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THE UNIVERSITY OF ALBERTA

AN ANALYSIS OF THE MEGAFOSSIL FLORA FROM THE
GENESEE LOCALITY, ALBERTA.

by



ASHTAKALA CHANDRASEKHARAM B.Sc.(Hons.) B.L., M.Sc.


A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN
PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF BOTANY

EDMONTON, ALBERTA

FALL, 1972.



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ABSTRACT

A large suite of over a thousand leaf compressions collected from a single outcrop at Genesee, Alberta has yielded 13 species with *Cercidiphyllum* and *Metasequoia* as a major association (nearly 80% of the collection). Utilization of qualitative and quantitative methods and comparisons of the range of variation between the fossils and their extant correlatives led to the delineation of three species of *Cercidiphyllum*. These are *C. genesevianum* sp. nov., *C. flexuosum* (Hollick) n. comb., and *C. cuneatum* (Newberry) n. comb.. *Azolla*, *Botrychium*, *Woodwardia*, *Glyptostrobus*, *Taxodium*, *Fokienia*, *Spirodela*, *Platanus*, *Tapiscia*, *Ampelopsis* and *Vitis* constitute the minor element of the flora. Remains of spongy mesophyll tissue, an unusual feature in fossils, was discovered and reported for the first time in *Cercidiphyllum*, *Platanus* and *Vitis*. Also reported for the first time are: vegetative remains of *Azolla schopfi* Dijkstra with reproductive structures *in situ* and branching axes of *Metasequoia occidentalis* (Newberry) Chaney bearing pollen cones.

Correlation of the flora with other floras has shown that the Genesee fossil assemblage is Paleocene in age. On the basis of flora and stratigraphy the fossiliferous beds were referred to the Scollard Member of the Paskapoo Formation (Irish, 1970). It was also pointed out that none of the forms considered by Dorf (1942) as the "best indices of

Lancian age" (Upper Cretaceous) was found in the Genesee suite.

A warm temperate, humid, winter-dry and summer-wet climate was inferred from floristic and vegetational analysis. Judging from the excellent preservation of the leaves, a poorly drained, quiet depositional environment with *Taxodium* and *Glyptostrobus* as swamp and *Metasequoia*, *Cercidiphyllum* etc., as stream-side vegetation was visualized.

part of the expenses for the thesis and for my visit to the Geological Survey of Canada, Ottawa, Harvard University Herbaria, the New York Botanic Garden, and the U.S. National Museum to study and collect data for my thesis. I would also like to thank the following individuals: Dr. C.R. Stalck of the department of Geology, University of Alberta, for making available the department's fossil collection from Genesee, Alberta. Dr. D.C. McGregor of the Geological Survey of Canada, Ottawa for making arrangements for my visit and enabling me to study the Survey's fossil collection. Dr. Gordon F. De Wolf Jr. of the Arnold Arboretum for making arrangements for my visit to the Arboretum and to make collections of plant material. Dr. Lorin I. Wierling Jr. of the Herbaria of Harvard University, for providing access to the Herbaria and giving permission to remove herbarium material for clearing. Dr. Herman F. Becker of the New York Botanic Garden, for making arrangements for my visit to the Garden and for sending fossil specimens up here for study. Dr. Francis W. Foster of the U.S. National Museum for making

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PREFACE

Deposited when no man trod this earth, buried in Time, sealed in shale and liberated at the strike of a steel hammer, the GENESEE FOSSILS, carbonized figures in sedimentary pages, indelible testimonials to Nature's craft, a treasure trove to a fossil hunter and a delight to a taxonomist, are a rare combination of beauty and detail holding secrets of a forgotten flora. Abundant in occurrence and exquisite in preservation the study of these fossils is the converging point of Nature's art and man's science.

CHAPTER 1

INTRODUCTION

The fossil locality at Genesee, Alberta has been known to amateur fossil collectors for many years. It is not an exaggeration to say that the locality easily ranks as the classical locality for early Tertiary floristic investigations of not only Alberta but also of western Canada. The fossil beds are famous for the remarkable and excellent leaf compressions which occur in profusion. The fossils are thus ideally suited for critical systematic studies.

This thesis places a special emphasis on the systematic aspect of the various species. Stratigraphy, age of the fossil beds, climatic consideration and local environmental changes at the time of deposition are treated as related topics.

Although the flora is not diverse in the number of species, nevertheless the study is a significant contribution to a better understanding of a segment of Alberta's floristic past.

Previous work

A serious study of the Genesee megafossils was made by Brayton (1953), when he completed a M.Sc. thesis based upon 400 "museum" specimens collected from Genesee. Assigning the Genesee fossil beds a position "approximately 40 feet below the 'Big Seam' and around 180 feet above the Knee

Hills Tuff", and based upon a comparison of the Genesee species with those of the type section Lance beds of Wyoming (Dorf, 1942) he concluded that the Genesee fossil flora was "(Lance equivalent in part?) of Maestrichtian (?) age...". The Big Seam referred to above is the correlative of the Ardley coal seam, exposed near the Genesee outcrop downstream and is known as the Coal Arch (Brayton, 1953). Brayton's identification of the species suffers from a number of deficiencies. A detailed criticism of the thesis is not attempted here. But a few pertinent comments with respect to the correctness of some of the species assigned are necessary.

Brayton considered the presence of four species *viz.*, *Anona robusta* Lesq., *Dombeyopsis colgatensis* Brown, *Trocho-dendroides arctica* Heer, *Vitis stantoni* (Knowlton) Brown in the Genesee assemblage as the "best direct index of Lance age....". Of the four species with the exception of *Trocho-dendroides arctica*, the rest are misidentifications. Since these species have a strong bearing on the age of the fossil beds a discussion of the species in some detail is in order.

Anona robusta Lesq.: Brayton (MS 1953, p. 36) described the leaf, without providing an illustration, as having a denticulate margin. Neither the original author (Lesquereux, 1883, p. 124, pl. 20, fig. 4) nor subsequent investigators (Dorf, 1942, p. 151; Bell, 1949, p. 61) described the species having a margin other than entire. Therefore, Brayton's specimen is not conspecific with *Anona robusta* Lesq. This specimen probably belongs to *Tapiscia serrata* (Newberry) n.

comb.. (See chapter 4).

Dombeyopsis colgatensis Brown: Brayton described the species as having "sinuate to slightly crenate" (MS 1953, p. 40) margin. The accompanying illustration (pl. 24, fig. 2) is of a fragmentary specimen showing no detail. In Brown's (1937, p. 252, pl. 60, figs. 1 to 4) account of *D. colgatensis*, a crenate margin was never mentioned. The species was described as having entire or undulate margin. In Dorf's (1942, p. 149, pl. 14, figs. 1, 4) report of the species from Lance flora no mention of a crenate margin was made. Therefore, Brayton's assignment of specimens to *Dombeyopsis colgatensis* is incorrect. This specimen belongs to *Cercidiphyllum cuneatum* (Newberry) n. comb.. (See chapter 4).

Vitis stantoni (Knowlton) Brown: Neither the original type specimen *Castalia stantoni* Knowlton (Knowlton, 1905, p. 147, pl. 19, fig. 4) nor Brown's *Vitis stantoni* (Knowlton) (Brown, 1937, p. 252; Dorf, 1942, p. 145; Bell, 1949, p. 75) can be matched with the fragmentary specimen of Brayton (MS 1953, p. 41, pl. 18, fig. 2). The illustrated specimen does not show details of the margin. This specimen belongs to *Ampelopsis acerifolia* (Newberry) Brown. (See chapter 4).

In view of these incorrect identifications the need has arisen to make new collections and re-examine the flora in all its aspects. The present study which encompasses a much larger collection and utilization of statistical treatments has enabled a clarification of some of the systematic problems. In addition, a few species were discovered and

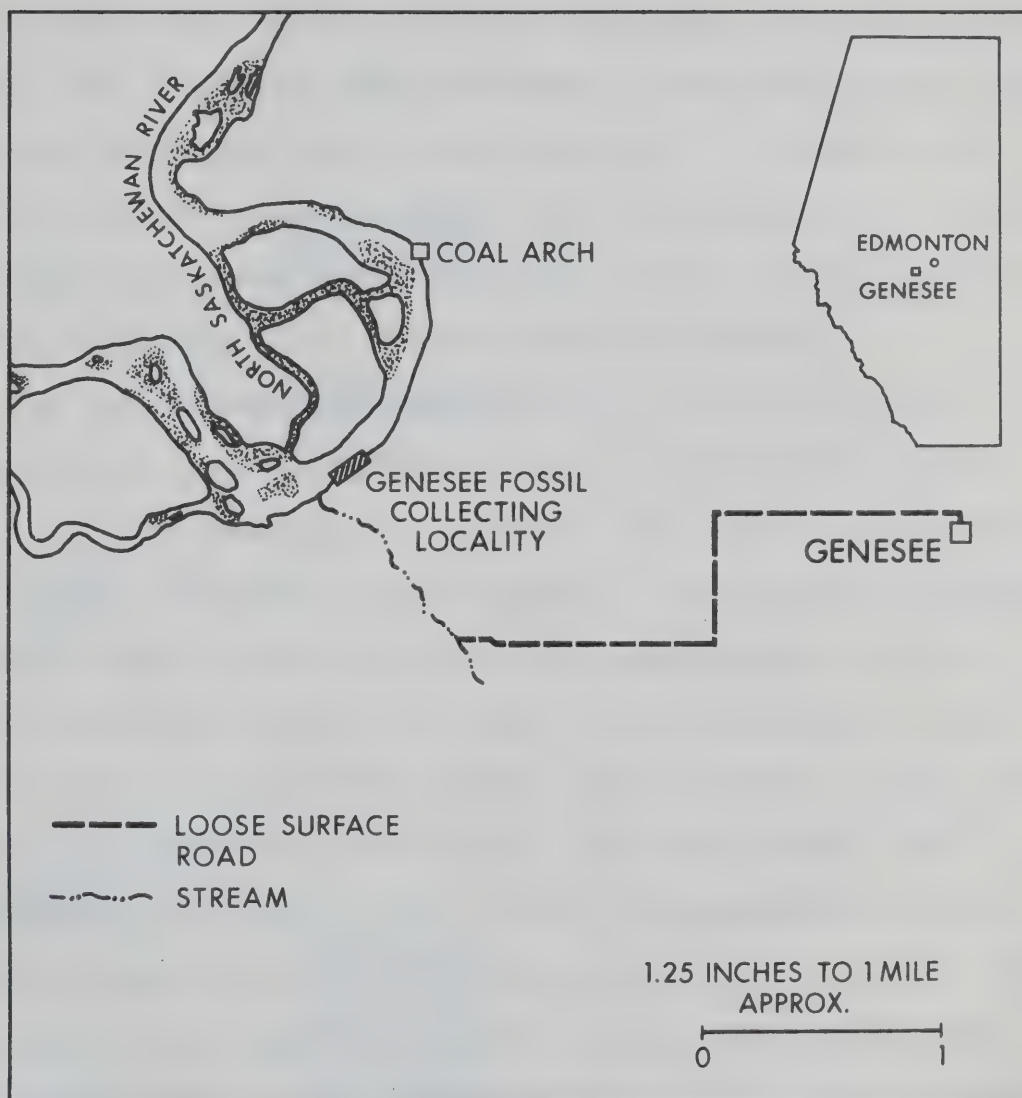
are reported for the first time.

CHAPTER 2

STRATIGRAPHY AND LOCALITY

The fossiliferous beds are exposed on the south bank of the North Saskatchewan River (pl. 1, figs. 1 to 5) about 45 miles west of Edmonton. Text-figure 1 shows the exact location of the fossil locality. Due to massive slumping the beds are exposed repeatedly at three levels, the highest level being indicated by the arrow in plate 1, figure 1. The lowest level occurs at the edge of water where, loose blocks of shale are exposed when the water level is low (pl. 1, fig. 2). At the highest level where the beds are *in situ*, they are usually covered by slumped glacial deposits, which overlie the beds, requiring massive digging to expose the beds (pl. 1, fig. 3). Figures 4 and 5 of plate 1 represent, in part, closer views of the beds illustrated in figure 3. The beds shown in figure 3 were exposed after digging. Figure 4 and 5 of plate 1 correspond, in part, to a portion of the section illustrated in text-figure 2. The symbols 'az' and 'an' in plate 1, figure 4, correspond respectively to "*Azolla*" and "*Metasequoia, Cercidiphyllum....etc.*," in text-figure 2.

Text-figure 2, illustrates the section, in part, of the outcrop and it is mainly intended to fix the position of the shale beds from which the fossils described in this thesis, were recovered. The figure is self-explanatory with respect to the stratigraphical sequence and no detailed description is attempted here except for a few points which require

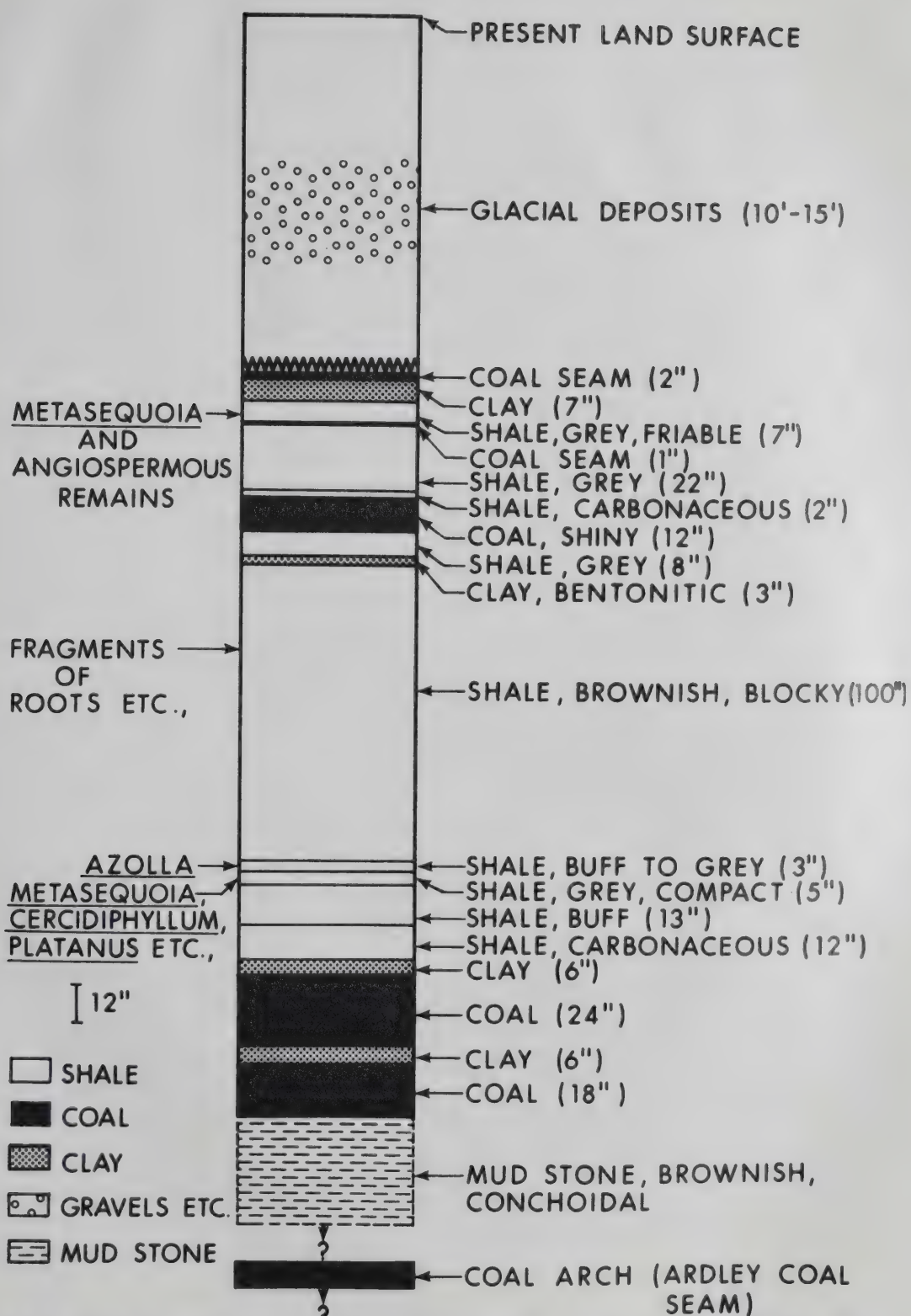


TEXT FIGURE 1

additional explanation. The shale beds comprise fine-grained sediments of volcanic origin interbedded by coal seams and bentonitic clay of variable thickness. The extent of the mudstone at the base of the section is unknown. The Coal Arch (Ardley Coal Seam) has been assigned a position 25 to 50 feet below the basal-most coal seam (text-fig. 2) (report from Dr. R.S. Taylor of Spence Taylor and Associates Ltd.). The Coal Arch is exposed downstream about a mile away from the section (text-fig. 2). Its thickness is unknown.

The stratigraphical separation of the fossils into "*Metasequoia*, *Cercidiphyllum*....etc.," and "*Azolla*" (text-fig. 2) is not clearcut but gradual; the labels only indicate the relative abundance of the genera. The majority of angiospermous remains along with very few gymnosperms occur as dense concentrations (pl. 1, figs. 6, 7) in greyish, fine-grained, well consolidated, hard, fissile shale, in the lower part of the section (text-fig. 2). In some places, the angiosperms grade above into a high concentration of *Metasequoia* to the exclusion of almost every other species. At other places angiospermous remains along with gymnosperms grade above into a high concentration of *Azolla* and *Spirodela*. *Azolla* and *Spirodela* occur in buff to grey, fine-grained, soft shale with a blocky fracture. In general, angiospermous remains, *Metasequoia* and *Azolla* succeed one another in an ascending sequence.

The lateral extent of the beds is not fully investigated and is unknown at present. Coal samples from the coal seams



TEXT FIG.2 SECTION (in part) OF THE OUTCROP AT GENESEE, ALBERTA.

were found to be poor in microfossils.

Plate 1.

Figs. 1-5. Fossil locality at Genesee.

Fig. 1. South bank of North Saskatchewan River near Genesee where the fossil beds are exposed. Arrow points to the highest level where the beds are *in situ*.

Fig. 2. Scattered loose blocks of fossiliferous shale at the edge of water.

Fig. 3. Front view of beds exposed after digging at the location indicated by the arrow in fig. 1.

Figs. 4,5. Nearer views of the beds shown in fig. 3.

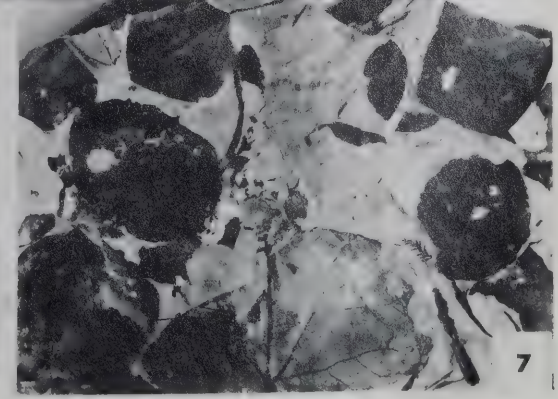
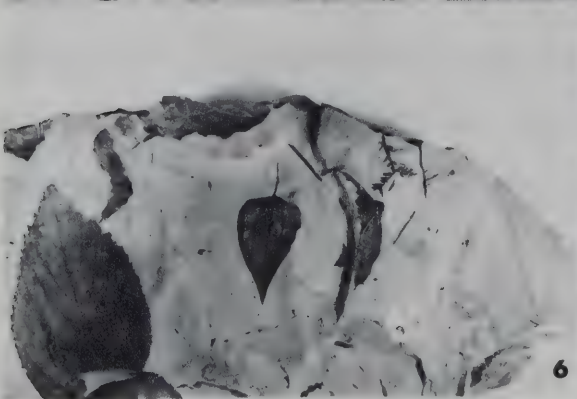
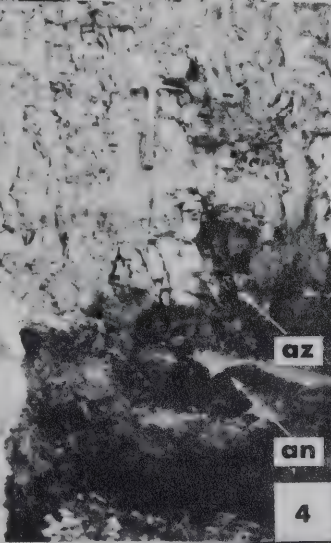
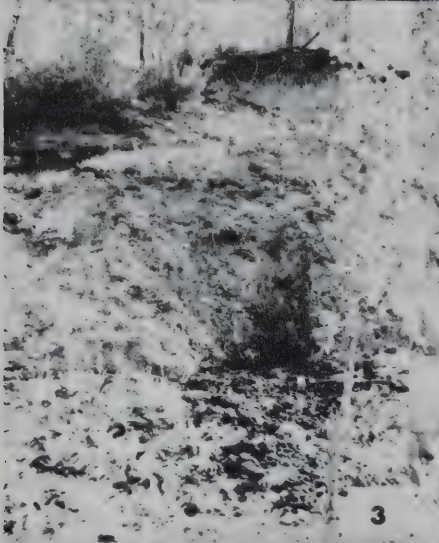
Fig. 4. 'az' and 'an' indicate the relative abundance of *Azolla* and angiosperm remains respectively.

Fig. 6. Large piece of shale with numerous angiosperm leaves. (S 1586 (A)) X 0.2.

Fig. 7. Large piece of shale with numerous angiosperm leaves. (S 885) X 0.2.

(Specimens shown in figs. 6,7 were collected from Genesee, Alberta).

PLATE 1



CHAPTER 3

MATERIALS AND METHODS

Fossil material: The organic remains comprising mostly leaves and reproductive structures, recovered from the Genesee fossil beds occur as compressions. Some of the angiosperm leaf fossils are iron-stained. To a casual observer these iron-stained leaves appear as dark, rust-coloured, structure-less impressions. Some of them, however, exhibit better detail than the ordinary compressions (pl. 20, figs. 135, 137). The foliar compressions are preserved flat in the shale. Petioles of angiosperm leaves, when preserved, usually dip into the shale, while the laminae themselves are flat. Leaves of *Metasequoia* and fruits of *Cercidiphyllum*, also dip into the shale. Most of the leaves show remarkable details of venation patterns, glands and remains of spongy mesophyll tissue. Some angiosperm leaves show small macroscopic carbonized spots, irregularly disposed on the laminae. The nature of these spots could not be determined. Depending upon their relative stratigraphical position in the fossiliferous beds correlated with the type of sediment, the organic remains show varying degrees of preservation. The position of the fossils in the stratigraphic section and the nature of the sediments are already described in the previous chapter.

The degree of preservation in a fossil, in general, is assumed to be the result of a number of interacting factors, physical as well as chemical, which operate on the organic

matter in the process of fossilization. This is a safe assumption in the case of leaf compressions because critical and extensive experimental evidence as to which factors are specifically responsible for a given degree of preservation is lacking at present. Physical and chemical factors referred to may include the size and chemical composition of the sedimentary particles, pH of the water and diagenetic processes.

The Genesee leaf fossils show a high degree of preservation of venation including the ultimate, freely-branching veinlets in the vein islets. It is interesting that while no recognizable cuticular remains were recovered, the leaves show well-preserved venation patterns. No speculation is possible at present as to the exact factors which were responsible for the fine preservation of venation to the exclusion of cuticles. It should, however, be recorded here that the cuticles of leaves of modern *Cercidiphyllum* were completely removed in a short time of two weeks when kept in a weak alkaline solution (2% sodium hydroxide). It can be inferred from this, that one of the factors responsible for the absence of cuticles might be a basic depositional environment.

The fossil material was collected in large quantities as randomly as possible.

Living material: Leaves of modern species of *Cercidiphyllum*, for comparison with fossils, were obtained from different plants that were growing in different localities of Japan. Some leaves were personally collected at random from mature

trees of *Cercidiphyllum* (70 to 80 years old) growing in the Arnold Arboretum and the New York Botanic Garden and a few leaves were obtained from a seedling growing in the green house at the University of Alberta. Herbarium material was also studied on a large scale from the Arnold Arboretum, the New York Botanic Garden and the Missouri Botanical Garden.

Methods

A number of methods (Darrah, 1936; Abbott, 1950; Dilcher, 1963; Cridland and Williams, 1966) were tried assuming that cuticular remains were preserved on the compressions. Full details of the methods devised by these authors can be had from their publications and are not repeated here except for a few explanatory notes. Darrah's (1936) and Abbott's (1950) methods are similar, i.e., the methods involve transferring the organic remains from the rock by means of a dried film. The method of Cridland and Williams (1966) involves the digestion of rock after the specimen is embedded in a suitable plastic. Dilcher's (1963) method is a bleaching process carried out with a 5% sodium hypochlorite solution. In addition to these methods a modified maceration method was tried. The method consists of bulk maceration of a piece of shale containing organic remains in concentrated hydrofluoric acid, followed by oxidation of the separated organic remains. The pieces of organic matter were oxidized, after removal from hydrofluoric acid and washing, by Schulze's mixture (concentrated nitric acid and potassium chlorate). No

cuticular remains were obtained by using any of the methods described above.

In addition, a simple modified peel technique was devised to further explore the possibility of recovering cuticular remains. Even after repeated trials by this method with different leaf compressions showing varying degrees of preservation, no cuticular remains were recovered. It was, therefore, concluded that cuticular remains were not preserved. The method is a modification of the acetate peel technique (North, 1956; Sinclair and Dunn, 1961; Stewart and Taylor, 1965) involving the following steps:

1. Wash the surface to be peeled in a gentle stream of water and dry thoroughly.
2. Keep the surface as level as possible.
3. Flood the surface with acetone.
4. Spread a sheet of cellulose acetate quickly to cover the surface.
5. Watch the acetate film contract and return to normal slowly. If air bubbles form while the peel is drying prick them with a needle and quickly mend the broken area by spreading a viscous mixture of acetone and cellulose acetate. The mixture, consisting of 100 sq mm of cellulose acetate film dissolved in 5 ml of acetone, is prepared beforehand and kept handy.
6. Let the film dry for about 7 to 10 minutes.
7. Pry the film with a needle or a razor blade from any convenient edge and peel off slowly. If the surface is

too uneven lift the peel gently from all edges around the specimen.

8. Place the peel in dilute (about 6%) hydrofluoric acid to remove the adhering rock particles.
9. When the peel is clear, wash thoroughly, dry between paper towels, cut to convenient size and mount dry or in Permunt; seal with a cover slip.

Comment: In step 1, the surface must be thoroughly dry; any trace of moisture on the specimen renders the peel cloudy.

Although the modified peel technique proved to be of no value in recovering cuticles, with respect to the Genesee fossils, the method was found useful for other purposes. Foliar remains from the Genesee locality occur in dense concentrations in blocks of shale. The leaves often lie one atop another with a thin layer of sediment in between. This situation presented a problem in attempts to expose a leaf lying immediately beneath another because the lower leaf could not be exposed without destroying the upper one. The modified peel technique was found valuable in transferring and preserving leaf compressions intact, which otherwise would have been destroyed. The peels in some instances were found useful in the study of venation patterns (pl. 28, fig. 192). When a peel was made for the purpose of salvaging a specimen, steps 8 and 9 of the method described above were eliminated. Peels were stored in envelopes after step 7.

Leaf clearing

As already stated, in the absence of experimental evidence no speculation can be advanced to explain the factors responsible for the fine preservation of venation in the Genesee fossils. However, the venation is preserved in such excellent detail, that it can be equated to a condition seen only in cleared leaves of modern plants. Therefore a number of cleared leaves were prepared (pl. 11, figs. 72, 73, 75) from modern species that are suspected correlatives of fossil species. The following clearing method was obtained from Dr. L. J. Hickey of U.S. National Museum and slightly modified.

(a) Equipment and chemicals: Petri dishes of various sizes; plastic screening (window mesh); hard rubber roller (photographic); forceps; 5% solution of sodium hydroxide; ethyl alcohol 100%; safranin 'O', 1% in ethyl alcohol and toluene; saturated aqueous solution of chloral hydrate; solution of ethyl alcohol 100% and toluene (1:2) for destaining; Permunt (mounting medium) for mounting; large glass slides or lantern slide glass plates.

(b) Procedure:

1. Place dried leaf in Petri dish, weight with plastic screening cut to size of the dish and cover with sodium hydroxide solution. Note that clearing with sodium hydroxide may take several weeks, depending upon the texture of the leaf.
2. Change solution at first daily and then at longer intervals

until it is clear. The leaf may not appear perfectly colourless when the solution is clear due to colouration of the cuticle or epidermis. Nevertheless it is ready for step 3.

3. Wash in a gentle stream of tap water to remove the clearing solution.
4. Soak leaf in chloral hydrate solution for several hours.
5. Wash.
6. Run through abbreviated dehydration series of alcohols to 100% ethyl alcohol. (10%, 50%, 90%, 100%).
7. Stain in safranin 'O' solution for approximately 30 minutes.
8. Destain in the ethyl alcohol and toluene solution for 5 to 15 minutes until desired contrast has been secured. Be careful not to destain the ultimate venation.
9. Transfer leaf into 100% toluene.
10. Place leaf between two glass slides and flatten it carefully with a hard rubber roller.
11. Mount in Permunt between two glass slides.

Statistical methods

It is well known to those who are familiar with the literature on megafossil floras of the Upper Cretaceous and Lower Tertiary, that a good number of publications are replete with doubtful species often erected on the slightest evidence (Ward, 1887; Newberry, 1898; Lesquereux, 1878; Hollick, 1930, 1936). Many of these species are based upon single fragments.

As Brown (1962) aptly puts it, "the fewer specimens a student has the more species he is likely to make". This shortcoming has been remedied to a large extent, with respect to Genesee fossils, by resorting to mass collecting. During collection, bias, in the sense of collecting only well-preserved specimens, was kept minimal. The best procedure under ideal conditions seems to be to collect quantities of fossiliferous shale at random without any bias whatsoever and analyse the contents in the laboratory. However, factors like transport of the fossil material, and inaccessibility of the site sometimes outweigh such an ideal procedure. In any event, a number of leaf compressions from the Genesee shale were, in fact, recovered in the laboratory.

Statistical analysis as applied to the Genesee mega-fossils, was done with a two-fold purpose. First, the fossils were collected in large numbers, as outlined above, to find out the range of variation and the relative frequencies of the various species. In spite of selective deposition of plant remains one can get a general idea about the floristic composition of the fossil locality including some ideas as to which species are dominant. Second, the morphological characters of the individual leaf compressions belonging to a species were statistically analyzed for taxonomic purposes. This aspect will be discussed in detail at the appropriate place (see chapter 4 and 'Appendix').

Measurements and numerical counts relating to venation, especially in *Cercidiphyllum* (see chapter 4 and 'Appendix'),

were made with the help of enlarged photographs. In some instances camera lucida was used for measuring ultimate venation.

Ecological associations

In identifying fossil leaves one must exploit all facets of evidence. Primarily this is achieved by a study of the morphology of the organs themselves. Sometimes such a study could be complemented by investigating ecological associations of species in modern floras (MacGinitie, 1941, 1969; Brown, 1962). This method has been used in the study of the systematic affinities of the Genesee fossil flora. For example, correlatives of an association of *Cercidiphyllum*, *Tapiscia*, *Metasequoia* identified in the Genesee flora, are found growing as ecological associates in south central China (Chu and Cooper, 1950).

CHAPTER 4

SYSTEMATIC DESCRIPTION OF THE FLORA

Introduction: A major portion (56%) of the Genesee collection comprises deciduous angiosperm leaves. Almost every investigator who has dealt with fossil floras composed of leaf remains has experienced some degree of difficulty in the interpretation of systematic relationships of the fossils. The basic problem is the proper identification of the fossil leaves. While earlier workers showed a tendency to create a large number of species disregarding the range of variation within a species, probably for the purposes of stratigraphy (MacGinitie, 1969), later investigators realized the need to treat the detached fossil leaves as biological entities rather than "practical species" (Brown, 1962, p. 36). Excellent treatments on all aspects of systematics in paleobotany relating to fossil leaves are given by Chaney (1938), Dorf (1942), Brown (1962), and MacGinitie (1969). Some of the problems related to the Genesee fossil flora are discussed at length in the section dealing with *Cercidiphyllum*.

In this thesis a conservative approach is used throughout in the identification of the fossil leaves, avoiding the creation of a large number of species treating them as biological entities, and taking into account the range of variation in each species. When a species found in the Genesee flora is made conspecific with another the original description of the species and later synonymies given by various authors are checked from published data. Since in

most cases original specimens are not available for comparative studies no lists of synonymies are included as such. However, species which bear resemblance to Genesee specimens are thoroughly discussed under each species. In the list of species to follow, various established classifications are followed. Thus ferns are classified according to the system used by Smith (1955); gymnosperms according to the classification given by Lawrence (1968) and angiosperms according to the system of Engler and Prantl as given by Willis (1966).

Systematic list of the flora and frequencies

Note: The numbers in brackets represent the number of specimens and the percentage of frequency respectively in the collection. Frequencies less than 1% are not recorded.

Class: Musci

Moss (1)

Class: Filicinae

Family: Ophioglossaceae

Botrychium sp. (1)

Family: Polypodiaceae

Woodwardia arctica (Heer) Brown (2)

Family: Salviniaceae

Azolla schopfii Dijkstra (40, 4%)

Incertae sedis: (3)

Class: Gymnospermae

Family: Pinaceae (1)

Family: Taxodiaceae*Glyptostrobus nordenskioldi* (Heer) Brown (8)*Metasequoia occidentalis* (Newberry)

Chaney (370, 36%)

Taxodium dubium (Sternberg) Heer (18, 2%)Family: Cupressaceae*Fokienia catenulata* (Bell) Brown (1)

Incertae sedis: (1)

Class: Angiospermae

Sub-Class: Monocotyledonae

Family: Lemnaceae*Spirodela scutata* Dawson (10)

Sub-Class: Dicotyledonae

Family: Cercidiphyllaceae*Cercidiphyllum genesevianum* sp. nov. (120,
12%)*C. flexuosum* (Hollick) n. comb. (150, 15%)*C. cuneatum* (Newberry) n. comb. (165, 16%)*Cercidiphyllum* sp. (7)Family: Platanaceae*Platanus raynoldsii* Newberry (20, 2%)Family: Staphyleaceae*Tapiscia serrata* (Newberry) n. comb. (54,
5%)Family: Vitaceae*Vitis* sp. (22, 2%)*Ampelopsis acerifolia* (Newberry) Brown

(29, 3%)

Incertae sedis (6)

Class: MUSCI

(Pl. 2, fig. 14)

Comment: This specimen comprises a cluster of gametophores with a length of 10 to 15 mm, with crowded spirally arranged leaves. The leaves are 2 mm long, broader proximally tapering off distally, i.e., lanceolate and costate. Most leaves are folded lengthwise along the costa. Some exhibit traces of square cells. A detached, dark, ovoid carbonized structure measuring 2 mm long and 1 mm wide (seen at upper right in pl. 2, fig. 14) bears a strong resemblance to a capsule probably belonging to one of the plants.

Judging from the morphology, the plant may belong to Dicranaceae or Ditrichaceae.

(Figured specimen bearing number S 101, was collected from the Genesee locality by Mr. Dennis Wighton and deposited in the paleobotanical collection, University of Alberta).

Class: FILICINAEFamily: Ophioglossaceae*Botrychium* sp.

(Pl. 2, figs. 10 to 13)

Comment: Fragments of foliage, and a single sporangiate axis were recovered. The foliage is too fragmented to give

a satisfactory description of the entire foliar complex. The fragments are chartaceous, pinnate in organization with open dichotomous venation (pl. 2, figs. 12, 13). The associated axis is 2 mm in width and 125 mm in length and is not complete. It is unbranched up to three fourths of its length, branching distally, the branches bearing successively smaller, crowded, globose structures with a diameter of 0.5 mm to 1.5 mm, alternately or oppositely (pl. 2, figs. 10, 11; in fig. 10 the arrow points to the axis).

The whole fragmented complex is quite similar to species of *Botrychium* especially, *B. virginianum* (L) Swartz. In the fossil specimen organic connection between the foliar fragments and the axis is lacking. Further collections may throw light on the exact systematic affinities of this specimen. Hence no specific epithet is appended at this time.

(Figured specimens bearing numbers S 1336 (L) and S 1337 (L) were collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta).

Family: Polypodiaceae

Woodwardia arctica (Heer) Brown

(Pl. 3, figs. 18, 19)

Comment: Only two sterile foliar fragments were recovered from the collection. The pinnae are about 85 mm long, chartaceous, with a finely serrate margin; venation consists of a midrib giving off veins to the pinnules. The veins fork repeatedly and extend to the teeth. Proximally the veins

anastomose forming large polygonal meshes.

Brown (1962) has satisfactorily explained how *Woodwardia* differs from *Onoclea*, in having a finely serrulate or conspicuously serrate margin. Specimens from Genesee can be favourably matched with a number of species assigned to *Woodwardia* and *Onoclea*. They are: *Woodwardia arctica* (Heer) Brown (Brown, 1962, p. 43, pl. 7, figs. 2, 3); *Woodwardia latiloba* Lesquereux (Lesquereux, 1878, p. 54, pl. 3, fig. 1a); *Woodwardia latiloba* var. *minor* Lesquereux (Lesquereux, 1878, p. 54, pl. 4, figs. 9, 9a); *Woodwardia latiloba serrata* Knowlton n. var. (Knowlton, 1930, p. 22, pl. 2, fig. 1); *Onoclea sensibilis* Linnaeus (Hollick, 1936, p. 35, pl. 2, figs. 3, 4).

Woodwardia arctica (Heer) Brown, is a Tertiary species.

(Figured specimens bearing numbers S 1615 (B) and S 2841 (B) were collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta).

Family: Salviniaceae

Azolla schopfii Dijkstra

(Pl. 3, figs. 15 to 17; pl. 4, figs. 21 to 26)

Azolla schopfii Dijkstra (Dijkstra, 1961)

Although there is considerable literature on dispersed reproductive structures of *Azolla*, reports of vegetative parts are scarce. Brown (1934) described vegetative remains of *Azolla berry* Brown from Green River Formation of middle Eocene age. Prior to Brown, Berry (1928) **described** *Azolla*

tertiaria Berry from the upper Miocene Esmeralda Formation. Neither author described reproductive structures. Vegetative remains with attached reproductive structures of *Azolla primaeva* (Penhallow) Arnold were described by Hills and Gopal (1967).

The Genesee specimens are remarkable for their preservation of vegetative parts with reproductive structures attached *in situ* (pl. 3, fig. 15, arrows; figs. 16, 17, arrows). The plant remains are sometimes superimposed on one another and occur in patches or mats (pl. 4, fig. 21).

The Genesee material was studied and identified by Dr. A. R. Sweet of Geological survey of Canada and will be the subject matter of a joint publication by him and the author at a future date. The following description and discussion is based and extracted from a manuscript prepared by Dr. Sweet.

Description: Fragmented stems (pl. 3, fig. 15; pl. 4, figs. 22 to 24) up to 5 cm or more long, pinnately branched, main axis dominant, internodes up to 4 mm long with a single leaf between two successive branches. Leaves bi-lobed ranging from widely spaced on main axis to imbricate at branch and stem apices (pl. 3, fig. 15). Dorsal and ventral leaf lobes with a prominent midrib; dorsal lobe up to 1.6 mm wide and up to 2.0 mm long, elliptic, obtuse at apex with well-developed hyaline margin of elongate cells up to 0.5 mm in width (pl. 4, fig. 26, arrows); margin entire. Ventral lobes up to 1.3 mm wide and up to 2.1 mm long, asymmetrical, of

single layer of cells. Stem pubescent (pl. 3, fig. 17), up to 2 mm in width. Roots with a single central vascular strand, usually in fascicles of 8 to 15 rootlets (pl. 4, fig. 25), rarely up to 3 rootlets only; rootlets 4 cm or more in length, 0.15 to 0.35 mm in width.

Comment: Forty specimens were recovered from the collection. Most of the plants are fertile bearing megaspore complexes (pl. 3, fig. 15 to 17, arrows), with one or two microspore bearing structures attached to the complexes (Jain, 1971). These complexes are easily visible to the naked eye as dark spots. As in extant species of *Azolla* the sporocarp is located in the axil of the lower most leaf of a branch. The roots are apparently attached to the stem at the location of a branch.

Discussion: The species *Azolla schopfii* Dijkstra was erected to circumscribe megaspore complexes recovered from a sample of the Ludlow Member, Fort Union Formation of Paleocene age from South Dakota. Snead (1969) reported megaspore complexes of *A. schopfii* from the Scollard Member of Paskapoo Formation. Jain (1971) described megaspore complexes with attached massulae containing microspores, attached to and in association with vegetative remains collected from the Genesee locality. He assigned a new name, *A. extincta*, to these reproductive complexes. A comparison of *A. extincta* with *A. schopfii* Dijkstra (Dijkstra, 1961; Snead, 1969) shows that the former is conspecific with the latter. Therefore, the description of *A. extincta* by Jain (1971) can be

considered only as an extension of the original diagnosis of *A. schopfii* to include the nature of the microspore bearing structures. In the present context, the circumscription of *A. schopfii* Dijkstra is expanded to include the vegetative structures.

Of the species of *Azolla* whose sporophyte has been previously described only *A. nilotica* is known to possess roots usually in fascicles (Demalsy, 1958). In addition to *A. schopfii* sharing this character with *A. nilotica*, the general form of the plants of these species is very similar both being very elongate, with a dominant main axis and with widely spaced leaves along the main axis and imbricate leaves only at the branch apices. These morphological similarities between *A. schopfii* and plants of subgenus *Rhizosperma* (in particular *A. nilotica*) suggest a closer relationship between *A. schopfii* and subgenus *Rhizosperma* than with subgenus *Azolla*.

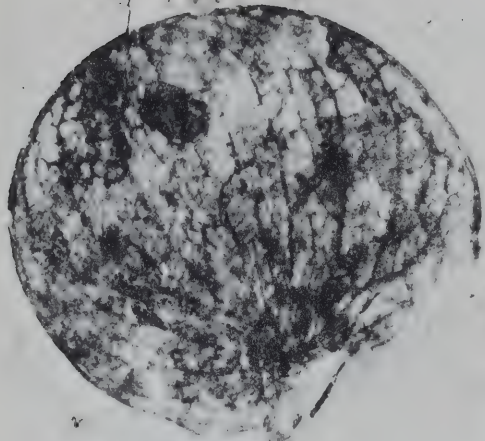
One trend in the evolution of the megaspore complex is the progressive reduction in float number (first proposed as an alternative hypothesis by Hills and Gopal (1967) and further discussed by Jain and Hall (1969)). Megaspore complexes of *A. schopfii* with 15 to 22 floats are more closely allied to those of subgenus *Rhizosperma* possessing 9 floats, than to the three floated megaspore complexes of subgenus *Azolla*. This is in agreement with the inference already drawn from sporophyte morphology.

The microspore bearing structure frequently found

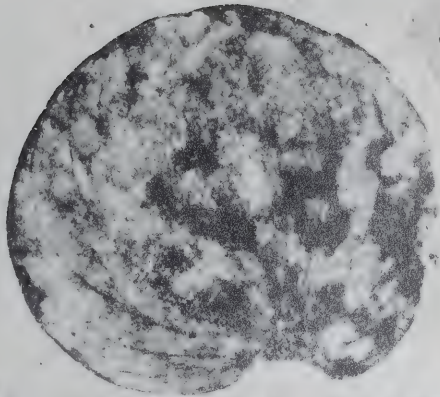
Plate 2.

- Figs. 8, 9. *Spirodelia scutata* Dawson. Fig. 8 (S 944) X 4.
 5. Fig. 9 (S 824) X 3.
- Figs. 10-13. *Botrychium* sp..
- Fig. 10. Branched sporangiate axis pointed by the arrow.
 (S 1336 (L)) X 0.7.
- Fig. 11. Enlarged distal view of the branched sporangiate axis shown in fig. 10. (S 1337 (L))
 X 1.8.
- Figs. 12,13. Venation of foliage associated with the
 sporangiate axis. (S 1337 (L)) X 1.3.
- Fig. 14. Moss. (S 101) X 3.

(Collected from Genesee, Alberta).



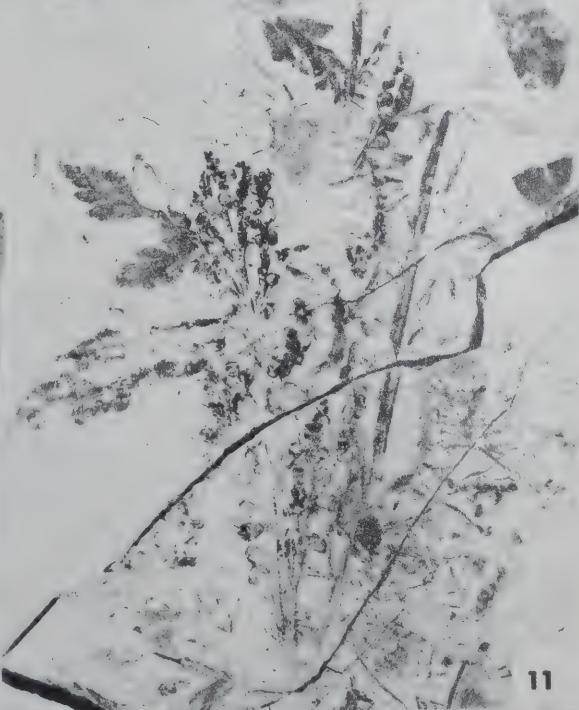
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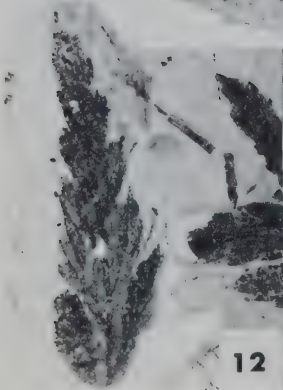
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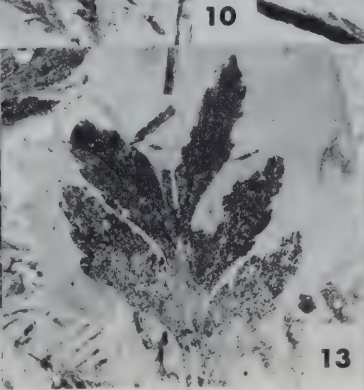
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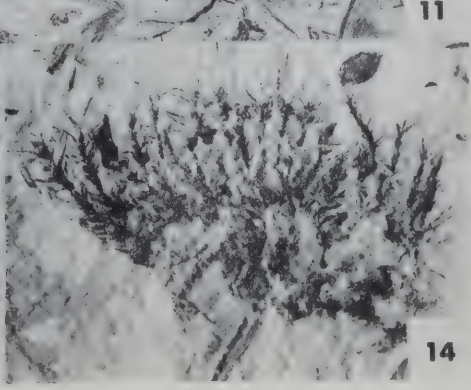
11



12



13



14

Plate 3.

Figs. 15-17. *Azolla schopfii* Dijkstra. Arrows in figures point to megaspore complexes. (S 1300). Fig. 15 X 2.2. Figs. 16, 17 X 9.

Figs. 18, 19. *Woodwardia arctica* (Heer) Brown. Fig. 18 (S 1615 (B)) X 0.9. Fig. 19 (S 2841 (B)) X 1.1.

Fig. 20. Incertae sedis. (S 393) X 3.6.

(Collected from Genesee, Alberta).

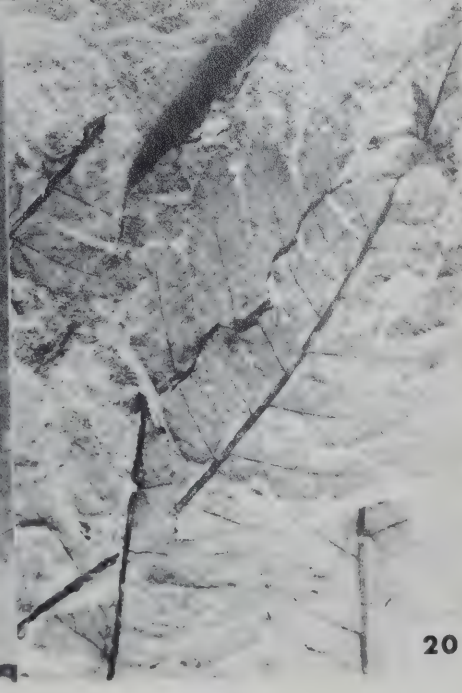
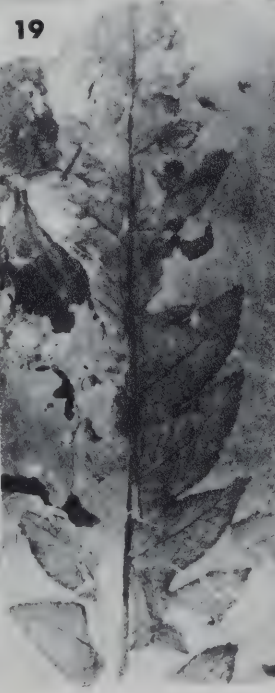
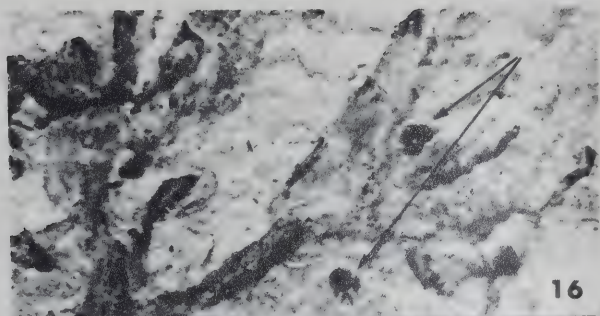
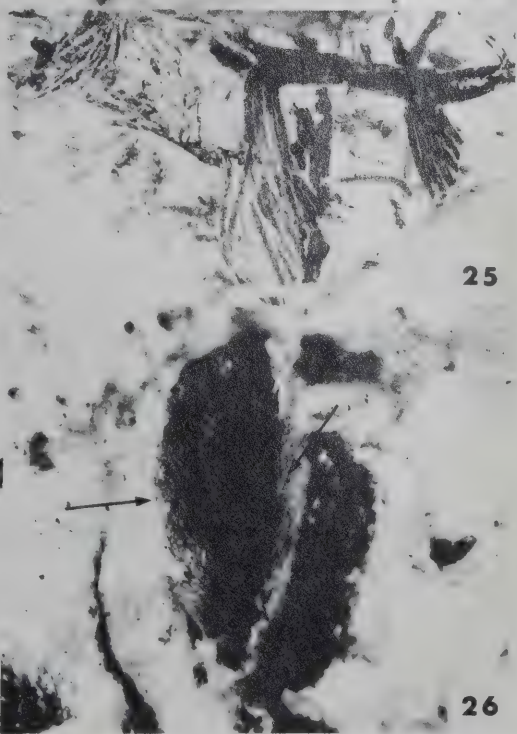
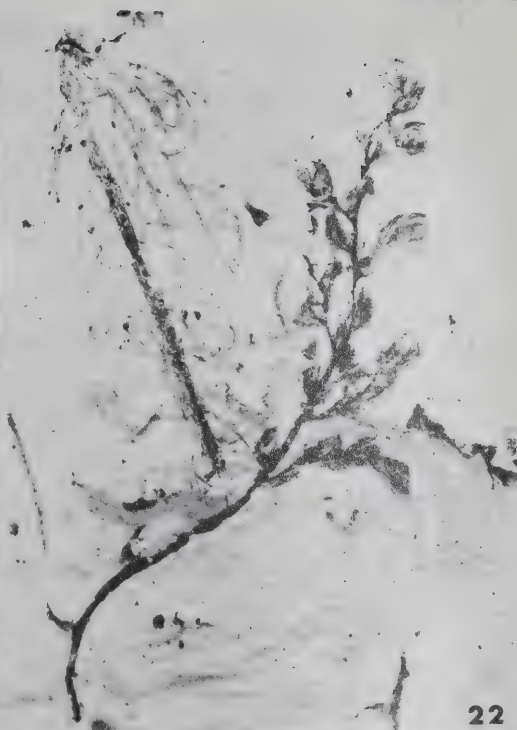
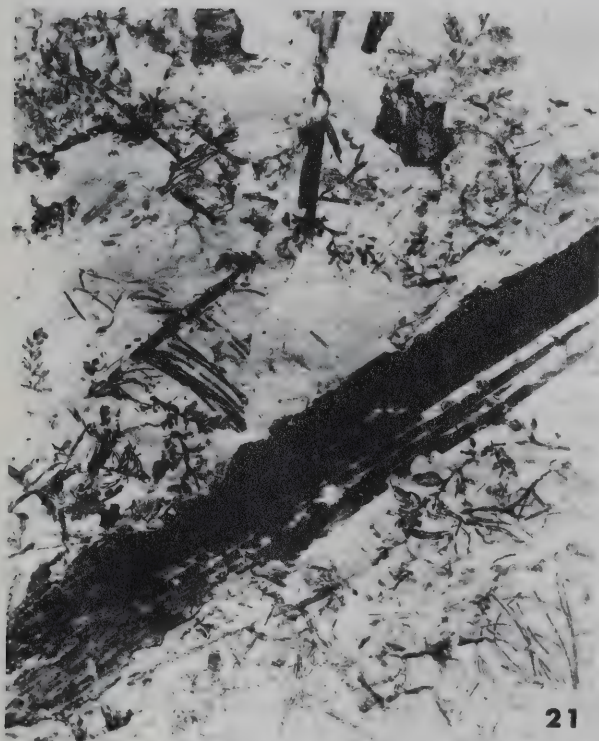


Plate 4.

- Figs. 21-26. *Azolla schopfii* Dijkstra. Fig. 21 (S 2836)
X 0.9. Fig. 22 (S 2233) X 3. Fig. 23 (S 2723)
X 3. Fig. 24 (S 1062) X 2.7.
- Fig. 25. Roots in fascicles. (S 970) X 2.7.
- Fig. 26. Dorsal lobe (left) of a leaf; arrows point to
cells in the hyaline margin. (S 1303 (L))
X 27.

(Collected from Genesee, Alberta).



species have fluke-tipped glochidia.

(Figured specimens bearing numbers S 2836, S 2233, S 2723, S 1062, S 970, S 1303 (L) and S 1300 were collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta).

Incertae sedis

(Pl. 3, fig. 20)

Comment: Three specimens comprising fragmented foliage were recovered from the collection. Pinnae are poorly preserved, chartaceous, margin of pinnules entire; pinnules are 10 mm long, base decurrent, joined together; central vein of pinnule is pinnately branched, the branches dichotomizing once; ends of dichotomies terminate at the margin.

The systematic position of the sterile foliage is uncertain.

(Figured specimen bearing the number S 393, was collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta).

Class: GYMNOSPERMAE

Family: Pinaceae

(Pl. 7, fig. 44)

Comment: A single, highly carbonized compression of a cone 78 mm long and 25 mm wide and with spirally disposed cone scales was recovered. The specimen can be favourably

compared to a female cone of *Picea*.

(Figured specimen bearing number S 845 (A) was collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta).

Family: Taxodiaceae

Glyptostrobus nordenskioldi (Heer) Brown.

(Pl. 7, figs. 41 to 43)

Comment: Eight specimens of the collection comprise this species. All of them are foliage shoots. Some of the shoots form a branching system (pl. 7, figs. 41 to 43) with shoots borne alternately on branches. The branch axis bears short, spirally and closely arranged, scale leaves. Foliage shoots bear dimorphic leaves i.e., proximal, spirally arranged, short, scale leaves and distal, linear, leaves. The linear leaves, are thin in texture with a prominent midrib, alternate, distichous, up to 12 mm long, 1 mm wide, with a decurrent base extending parallel to the axis as in *Taxodium*. The linear leaves are more widely spaced than the scale leaves, and diverge at an angle of 25-45°.

Herbarium material of the living *Glyptostrobus pensilis* Koch was compared with the Genesee material. The living species shows cryptomeroid, cupressoid and taxodioid (Brown, 1962) foliage. The taxodioid type of leaves are linear, alternate, distichous, decurrent, with the base parallel to the axis. This condition is best observed in shoots in which the leaves are inserted at some distance from one another and

diverging at wide angles, between 70 to 80° from the axis. The nature of the decurrent base is not well-defined in shoots bearing leaves which are crowded, spirally arranged and inserted at low angles, i.e., less than 45°. The same situation described here is seen in the Genesee fossils.

Discussion: The assignment of the meagre and fragmentary foliage, without reproductive structures, collected from Genesee, to *Glyptostrobus nordenskioldi* (Heer) Brown, is made with some reservations. Leaves of extant *Glyptostrobus* and *Taxodium*, especially the linear type, are indistinguishable. As commented on above, the mode of insertion of leaves in both genera seems to be identical. The only difference appears to be in the spacing of the scale leaves. In *Taxodium* they are crowded together forming an enlarged bulbous cluster at the base of the foliage shoot. In *Glyptostrobus*, on the other hand, they are slightly more widely spaced without forming an enlarged cluster at the base. This condition is also seen in the fossils (pl. 7, fig. 43). These observations are based on a few twigs of herbarium material of *Glyptostrobus* and living specimens of *Taxodium* and require verification based on a larger suite of material, both living and fossil.

Among the fossil species described from various localities, the following can be matched with the Genesee specimens. *Sequoia nordenskioldii* Heer? (Newberry, 1898, p. 20, pl. 26, fig. 4). The line drawing by Newberry shows fragments of shoots bearing linear leaves only. His

description in the text, however, mentions two kinds of leaves, short and linear. His description could be matched with the Genesee specimens. *Cryptomerites lambii* Bell (Bell, 1949, p. 49, pl. 30, fig. 5, specimen to the left); *Elatocladus* (*Cryptomerites*?) *nordenskioldi* (Heer) Bell (Bell, 1949, p. 50, pl. 31, fig. 3); *Glyptostrobus europaeus* (Brongniart) Unger (Hollick, 1936, p. 51, pl. 17, figs. 1 (part), 2 to 4; pl. 104, fig. 7b; pl. 109, fig. 11). Hollick says that some of his specimens are difficult to distinguish from *Taxodium dubium* (Sternberg) Heer.

(Figured specimens bearing numbers S 1013 (B), S 272 and S 3152 were collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta).

Metasequoia occidentalis (Newberry) Chaney
(Pl. 5, figs. 27 to 32; pl. 6, figs. 33 to 37; pl. 39, figs. 245, 246, 248, 249).

An exhaustive historical study encompassing the inter-relationships of *Metasequoia*, *Sequoia* and *Taxodium*, living and fossil, was made by Chaney in 1951. Remains of *Metasequoia* recovered from Genesee are conspecific with his combination *Metasequoia occidentalis* (Newberry) Chaney.

Comment and discussion: This species is the major component of Genesee megafossil flora next to *Cercidiphyllum*. Three hundred and seventy specimens including 10 pollen cone-bearing axes and 4 seed cones were recovered from the collection. While most specimens are deciduous short shoots

(pl. 6, fig. 33; pl. 39, fig. 249), a few deciduous branches bearing short shoots are seen (pl. 5, fig. 27; pl. 39, figs. 245, 246). The term 'branch' used here is equivalent to a long shoot. Moreover, in the extant *Metasequoia glyptostroboides* Hu and Cheng, the distinction between long and short shoots can be made out not only by the fate of a particular shoot but also by the morphology of the leaves borne on it. Thus, a foliage shoot borne by a long shoot may develop into a long shoot, or remain as a short shoot. Long shoots, which are usually persistent are of indeterminate growth; short shoots are deciduous and of determinate growth (Chaney, 1951; Hui-Lin Li, 1964). Long shoots bear opposite, distichous short shoots or sometimes, one of the opposite pairs of short shoots may be absent (pl. 5, fig. 27. Compare this figure with pl. 2, fig. 2, illustrated in Chaney, 1951). Chaney's statement in this context that, "a large needle occupies its place" (p. 177) referring to the undeveloped short shoot of an opposite pair, is incorrect, leading to the inference that a cauline structure is replaced by a foliar organ. In higher plants cauline structures are always subtended by foliar organs and one does not replace the other. Long shoots bear leaves up to three times longer than those borne on short shoots and fall off if they are not well established with the onset of winter (Chaney, 1951). A few fossils show this condition (pl. 5, fig. 28; pl. 39, figs. 246, 248). In the modern *Metasequoia glyptostroboides* short shoots grow from the axils of some of the long shoot leaves

here and there without any regular pattern. The same condition is observed in some specimens collected from Genesee (pl. 5, fig. 28; pl. 39, figs. 245, 246). The specimen figured in plate 5, figure 28 is nearly identical to those figured by Chaney (1951, pl. 4, figs. 8, 9). It is also interesting to note short shoots in various stages of development starting from buds (pl. 39, figs. 245, 246). Arrows in figure 245 and the top most arrow in figure 246 point to small, structureless carbonized masses inferred to be buds judging from their analogous position in the living plant. Further, such an inference could be drawn from the fossil specimen (pl. 39, fig. 246) which exhibits successive growth stages of short shoots axillary in position.

Chaney's choice of the term 'bracts' (1951, p. 178) referring to the cluster of scale-like leaves found at the base of the short shoots, which is seen as a slightly enlarged, bulbous, carbonized mass in fossils (pl. 6, fig. 33; pl. 39, fig. 249), is inappropriate. The term 'bract' is a morphological term traditionally applied to a foliar organ in association with reproductive structures like flowers and cones. The term scale leaf, is preferable in describing a foliar organ associated with a vegetative structure. It must, however, be noted that Chaney does not use the term bract in his specific description of *Metasequoia occidentalis* (p. 225). The short shoots bear on average 28 pairs of leaves with a range of 20 to 32 pairs; leaves show a mean length of 15 mm and a mean width of 2 mm. In long shoots, the length

reaches up to 25 mm. The mucronate apex on leaves referred to by Chaney (1951, p. 178) is not observed in the Genesee specimens.

Seed cones attached to stalks are rare. Only one was recovered (pl. 6, fig. 34). In size the smallest cone is 11 mm long and 6 mm wide, ovoid, elongate in shape (pl. 6, fig. 37); the largest is 40 mm long and 31 mm wide, globose in shape (pl. 6, fig. 35).

Pollen cones are borne on simple or branched axes (pl. 5, figs. 29 to 32; pl. 6, fig. 36). The cones show a range of 1 mm to 5 mm in length and 0.5 mm to 4 mm in width. In one specimen, for the first time, a transition from a proximal vegetative region, to a distal fertile region is seen (pl. 5, fig. 30). Although never figured, Chaney (1951, p. 227) made a suggestion with respect to the attachment of detached shoots bearing pollen cones, on compound branching axes. For the first time, branching axes bearing pollen cones, recovered from the Genesee collection, bear out his suggestion (pl. 5, figs. 29, 31, 32). Pollen cones, described here are highly carbonized and do not show any detail. In fact, the small cones can hardly be distinguished from the buds mentioned above in connection with long shoots. The only way they could be distinguished appears to be in their organization. Thus pollen cones are borne in the axils of each successively opposite pair of leaves (pl. 5, figs. 29 to 32, pl. 6, fig. 36), while vegetative buds are borne without such a regular pattern (pl. 39, figs. 245, 246).

This observation needs further confirmation based on extensive studies of living material.

A number of Genesee specimens can be matched with specimens figured by Chaney (1951). *Metasequoia occidentalis* has been reported by Koch (1963) from the lower Paleocene of northwest Greenland. Some of the specimens described and figured by him are identical with the Genesee specimens (compare his pl. 4, fig. 2, seed cone with pl. 6, fig. 35 of this thesis).

Metasequoia occidentalis (Newberry) Chaney is a wide-spread species, both stratigraphically and geographically. It has been reported from the western United States, western Canada, and circum-polar regions, ranging from late Cretaceous (Shoemaker, 1966; Rouse, 1967) through Tertiary up to middle Miocene time (Chaney, 1951; Schloemer-Jäger, 1958; Brown, 1962; Koch, 1963; Becker, 1969). It survived into the Pliocene epoch in Japan, with *Metasequoia glyptostroboides* Hu and Cheng as the surviving relict in southern China.

(Figured specimens bearing numbers S 353, S 3151, S 842, S 1343, S 961, S 946, S 1533, S 910, S 1341, S 2867 (A), S 1540 (A) and 1540 (B) were collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta).

Taxodium dubium (Sternberg) Heer

(Pl. 7, figs. 39, 40; pl. 39, fig. 244)

Comment: Eighteen specimens including fragments, all

detached foliage shoots, were recovered from the collection. Eight shoots are complete. No branching systems were observed. The detached shoots, presumably short shoots, are of variable length ranging from 30 to 106 mm. The shoots bear 15 to 50 'pairs' of linear leaves, with a basal cluster of scale leaves which form a bulbous, enlarged base. Linear leaves diverge from the axis at a mean angle of 50° with a range of 40 to 60° . They are alternate, distichous and slightly curved abaxially giving a lax appearance; leaves are of variable length and width, with a mean length of 6 mm and a range of 4 to 7 mm and a mean width of 1 mm with a range of 0.5 to 2 mm. Their shape is variable, oblong with parallel or slightly curved margins (pl. 7, fig. 40) or elliptic (pl. 7, fig. 39) with an acute tip. The bases of leaves are decurrent with the entire line of attachment parallel to the axis.

Discussion: No reproductive structures assignable to this species were found. This might be due to its relatively rare occurrence in the Genesee megafossil flora. The same is true of *Glyptostrobus nordenskioldi* (Heer) Brown as indicated elsewhere in this thesis.

Chaney (1951) thoroughly reviewed the literature relating to three taxodiaceous genera *Metasequoia*, *Sequoia* and *Taxodium*, and re-examined extensive fossil collections of United States and Canada. He assigned a number of species to two new combinations viz., *Metasequoia occidentalis* (Newberry) Chaney, a predominantly Tertiary species, which

Shoemaker (1966) and Rouse (1967) have recorded from the Upper Cretaceous and *M. cuneata* (Newberry) Chaney, a predominantly Cretaceous species. He also revised the status of *Taxodium dubium* (Sternberg) Heer, and two species of *Sequoia*. While his circumscription of *Metasequoia occidentalis* is sound, Chaney's *M. cuneata* appears to be inconsistent, especially with respect to the species listed in his synonymy (p. 229). Before pointing out the inconsistencies it is worthwhile to review briefly the criteria which he considered to be significant and constant when distinguishing among the foliage in the three genera, *Metasequoia*, *Sequoia* and *Taxodium*. These criteria are, the mode of insertion of the leaves and the alignment of their decurrent bases. In *Taxodium* the insertion is at right angles to the axis of the shoot and in *Sequoia* and *Metasequoia*, it is oblique. In *Taxodium* the leaf base is parallel to the shoot axis all the way; in *Metasequoia* it is twisted and oblique all the way down to the subjacent leaf; in *Sequoia* the base is oblique for a short distance and then parallel to the axis (Chaney, 1951, p. 179). The relative significance of the phyllotaxy of the leaves (decussate in *Metasequoia*, spiral in *Sequoia* and *Taxodium*) was not specially emphasized by Chaney, even though it is an obvious feature drawing immediate attention in any fossil foliage fragment. It must be mentioned, however, that the phyllotaxy in *Metasequoia* and *Taxodium* is subject to slight variation requiring a large scale statistical investigation. It is quite probable that Chaney

(1951) was aware of this variation. Arnold and Lowther (1955), point out that leaves of *Taxodium* possess a mucronate tip as in *Sequoia* and *Metasequoia*, while Chaney recorded the tip as acute (1951, p. 180). As mentioned elsewhere, the linear leaves of *Glyptostrobus pensilis* Koch also show a decurrent base, which runs parallel to the axis as in *Taxodium*. This observation lessens the value of Chaney's "constant" criteria, for distinguishing the foliage of *Metasequoia*, *Sequoia* and *Taxodium*.

In any event, some of the Genesee specimens included here under *Taxodium dubium* (Sternberg) Heer, can be favourably compared with figured specimens of species listed by Chaney (1951) in his synonymy of *Metasequoia cuneata* (Newberry) Chaney. The problem here is two-fold: either the assignment of the Genesee material to *Taxodium dubium* is wrong, which in fact must be referred to *Metasequoia cuneata* or that Chaney was in error in his list of synonymy of *Metasequoia cuneata*. But, as commented on above, the Genesee specimens are clearly taxodioid according to Chaney's own criteria. Therefore, Chaney's synonymy of *M. cuneata* were re-examined and a few of the species which were found to resemble the Genesee specimens are briefly discussed:

Sequoia cuneata Newberry (Newberry, 1898, p. 18, pl. 14, figs. 3, 4a): Newberry's illustrations are of fragments showing leaves disposed alternately. *Sequoia brevifolia* Heer (Lesquereux 1878, p. 78, pl. 61, fig. 26): this specimen shows leaves of sub-opposite (alternate) phyllotaxy

though Chaney (1951, p. 207) claims that they are opposite, the leaves showing a shape similar to Genesee specimens; (Knowlton, 1900, p. 27, pl. 4, figs. 1 to 3): Knowlton's line drawings show leaves arranged in a sub-opposite phyllotaxy. *Sequoia obovata* Knowlton (1917, p. 250, pl. 30, fig. 7): the specimen from Upper Cretaceous deposits (Vermajo) illustrated by Knowlton shows some leaves in sub-opposite insertion, though Chaney records that Knowlton's specimens exhibit opposite phyllotaxy and hence are referrable to *Metasequoia* (1951, p. 214). It must be stated here that the foregoing analysis is based upon descriptions and illustrations. A study of the original specimens may reveal answers to these discrepancies. A few Genesee specimens resemble the material figured by Bell (1957, p. 31, pl. 17, fig. 7 in part) as *Metasequoia cuneata* (Newberry) Chaney pars.

Bell (1957) amended the description of *Metasequoia cuneata* (Newberry) Chaney. The exact nature of the decurrent base was not mentioned in Bell's description. This is significant since Chaney (1951) had shown, after a thorough revision, that the nature of the leaf base is a good character in distinguishing *Metasequoia*, *Sequoia* and *Taxodium*. Further, Bell (1957) lists four characters in which *Metasequoia cuneata* differs from *M. occidentalis*, one of them being the "lack of evidence for scale-like leaves at the base of the short shoots" in *M. cuneata* (p. 31). Some of the well-preserved foliage shoots collected from Genesee exhibit a bulbous, enlarged base consisting of a cluster of

closely spaced scale leaves (pl. 39, fig. 244). Inasmuch as these specimens are probably identical with the specimens figured by Bell (1957) under his *M. cuneata*, the Genesee specimens provide the evidence for scale leaves he was seeking. By the same reasoning the presence or absence of scale leaves ceases to be a character of distinction between *M. cuneata* and *M. occidentalis*. In conclusion it may be said, that the taxonomic status of *M. cuneata* (Newberry) Chaney is in need of more critical study based upon a statistical treatment of the living taxodiaceous genera.

Specimens assigned here to *Taxodium dubium* (Sternberg) Heer, exhibit a considerable range of variation in leaf shape. Chaney (1951) also attests to this fact, when he says that the leaves of *Taxodium* have a wider range in shape than those of *Metasequoia* and *Sequoia*, varying from linear to almost the proportion of *Sequoia*.

Of the long list of species given by Chaney (1951) under *Taxodium dubium* (Sternberg) Heer, only one, *Taxodium crassum* Hollick (Hollick, 1936, p. 48, pl. 16, fig. 9), can be closely matched with the Genesee specimens. Among the specimens of *Taxodium dubium* figured by Chaney (1951) his figure 9 of plate 12, is nearly identical to most of the Genesee specimens (pl. 7, fig. 40; pl. 39, fig. 244; S 359; S 303).

(Figured specimens bearing numbers S 1068, S 1007 and S 879 were collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta).

Family: Cupressaceae

Fokienia catenulata (Bell) Brown.

(Pl. 7, fig. 38)

Comment: Only one fragment was discovered. It is 40 mm long and highly carbonized without showing any trace of venation. It is made conspecific with Brown's (1962) new combination *Fokienia catenulata* which is based upon Bell's (1949) *Androvettia catenulata*. The specimen collected from Genesee compares favourably with *Androvettia catenulata* Bell (Bell, 1949, pl. 15, figs. 1, 2; pl. 16, fig. 4), *Fokienia catenulata* (Bell) Brown (Brown, 1962, pl. 11, fig. 1).

Both Bell (1949) and Brown (1962) report the species from Paleocene strata.

(Figured specimen bearing the number S 2820 (A) was collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta).

Incertae sedis

(Pl. 39, fig. 247)

Besides the species described above, a single detached cone attached to a stalk 40 mm long was discovered in the Genesee collection. The cone is highly carbonized, pyriform in shape with a length of 8 mm and a maximum width of 6 mm. One foliar appendage can be faintly seen attached to the stalk. Outlines of cone scales, arranged spirally, were observed after scraping the carbon away. This is not seen

Plate 5.

Figs. 27-32. *Metasequoia occidentalis* (Newberry) Chaney.

Fig. 27 (S 353) X 1.

Fig. 28. Short shoots in the axils of leaves borne on long shoots. (S 3151) X 0.9.

Fig. 29. Pollen cones borne on a branching system. (S 842) X 1.

Fig. 30. Pollen cones borne on a simple axis. Note proximal sterile portion. (S 1343) X 0.9.

Figs. 31,32. Pollen cones borne on branching systems.

Fig. 31 (S 961) X 1.5. Fig. 32 (S 946) X 1.2.

(Collected from Genesee, Alberta).

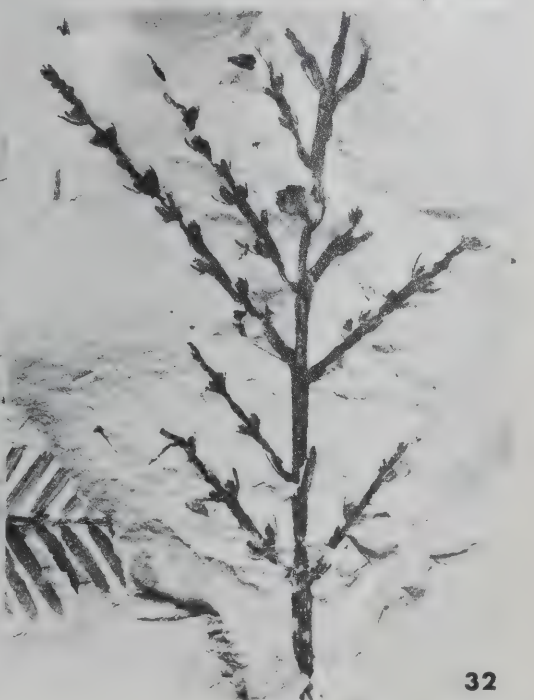
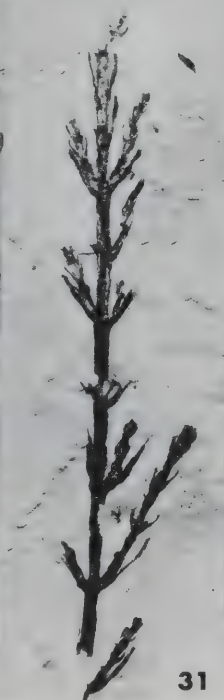
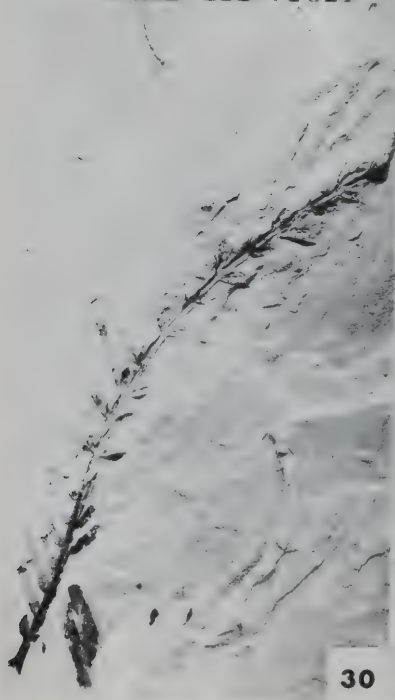
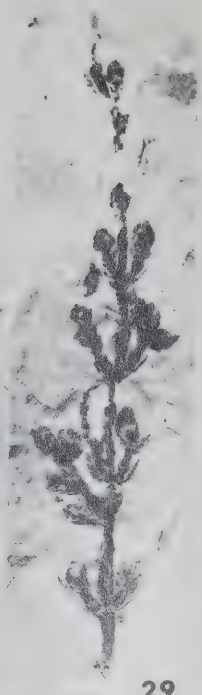


Plate 6.

Figs. 33-37. *Metasequoia occidentalis* (Newberry) Chaney.

Fig. 33 (S 1533) X 1.3.

Fig. 34. Stalked seed cone. (S 910) X 1.2.

Fig. 35. Seed cone. (S 1341) X 1.

Fig. 36. Pollen cones. (S 2867 (A)) X 1.1.

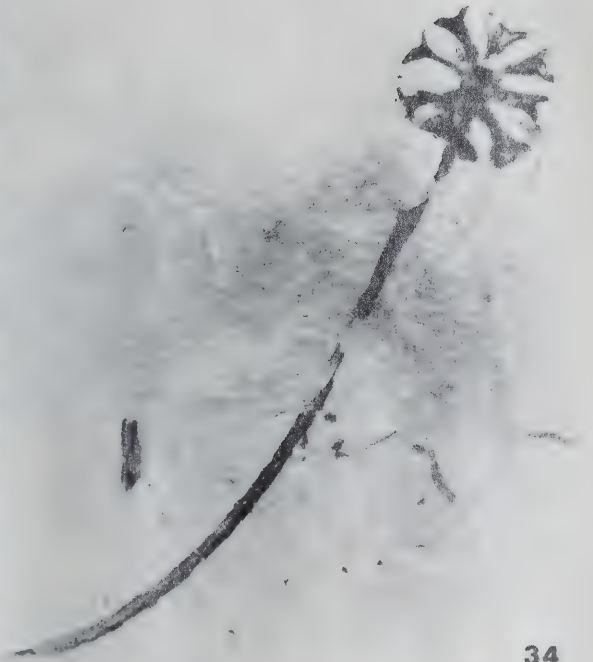
Fig. 37. Seed cone (counter parts). (S 1540 (A) and (B)) X 2.2.

(Collected from Genesee, Alberta).

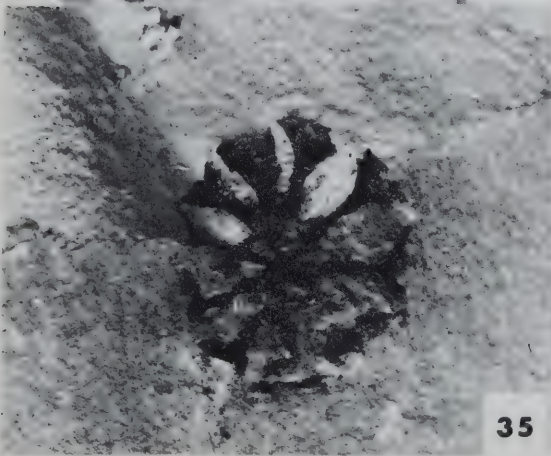
PLATE 6



33



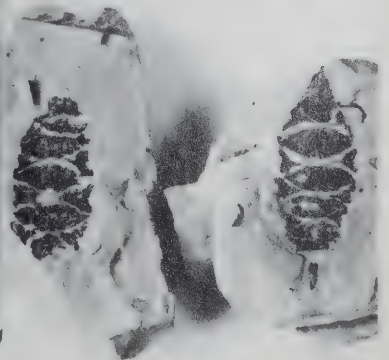
34



35



36



37

Plate 39.

- Fig. 244. *Taxodium dubium* (Sternberg) Heer. (S 879)
 X 1.6.
- Fig. 245. *Metasequoia occidentalis* (Newberry) Chaney.
 Arrows indicate axillary buds. (S 795) X 1.
- Fig. 246. *Metasequoia occidentalis* (Newberry) Chaney.
 Arrows indicate successive growth stages of
 short shoots in the axils of leaves. Upper-
 most arrow points to a bud. (S 795) X 2.3.
- Fig. 247. Stalked cone (*incertae sedis*). (S 2837) X
 2.3.
- Figs. 248,249. *Metasequoia occidentalis* (Newberry) Chaney.
 Fig. 248 (S 1038 (A)) X 1. Fig. 249 (S 770
 (B)) X 1.3.
 (Collected from Genesee, Alberta).

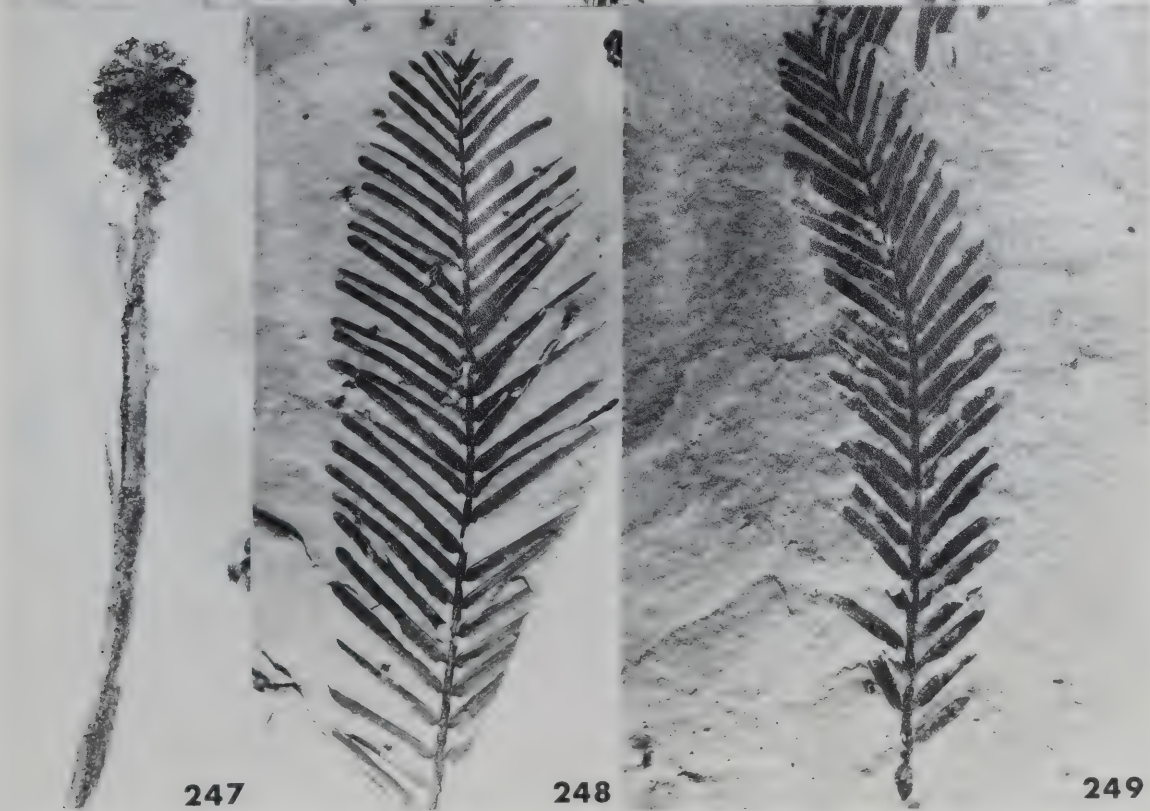
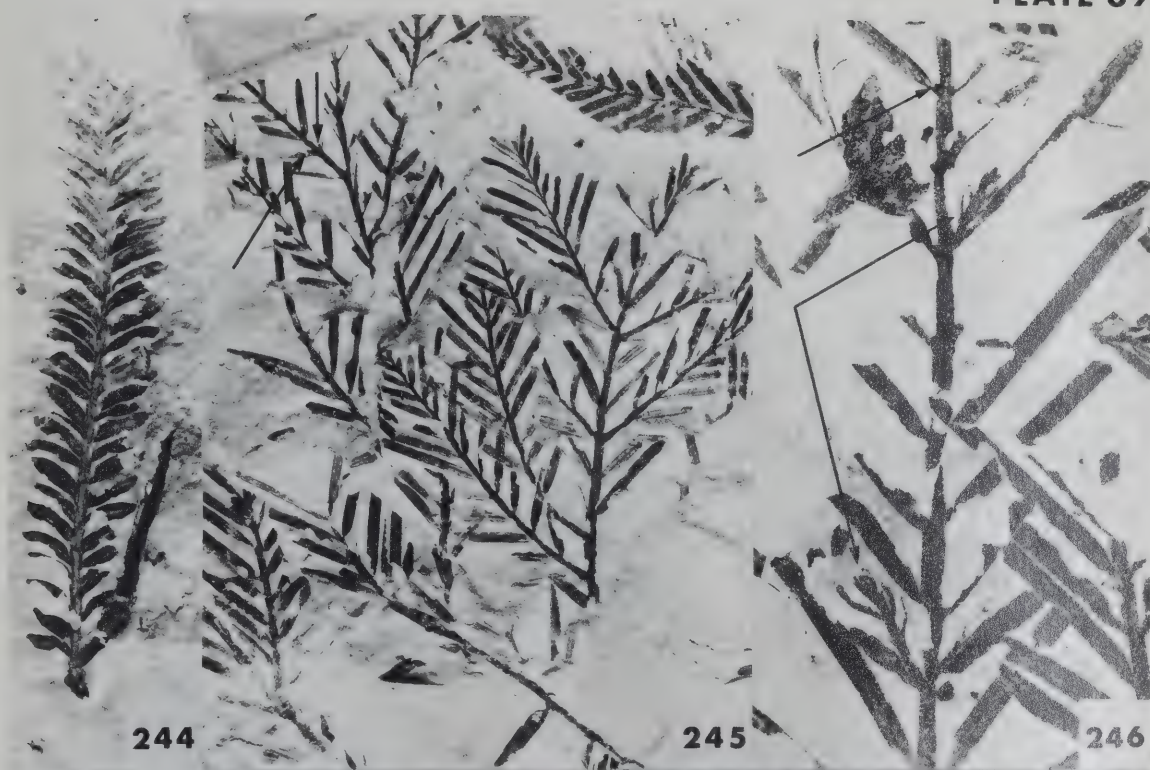


Plate 7.

Fig. 38. *Fokienia catenulata* (Bell) Brown (S 2820) X
1.7.

Figs. 39, 40. *Taxodium dubium* (Sternberg) Heer. Fig. 39
(S 1068) X 2.9. Fig. 40 (S 1007) X 2.

Figs. 41-43. *Glyptostrobus nordenskioldi* (Heer) Brown.
Fig. 41 (S 1013 (B)) X 1.8. Fig. 42 (S 272)
X 1. Fig. 43 (S 3152) X 1.1.

Fig. 44. Female cone belonging to Pinaceae, probably
Picea. (S 845 (A)) X 1.3.

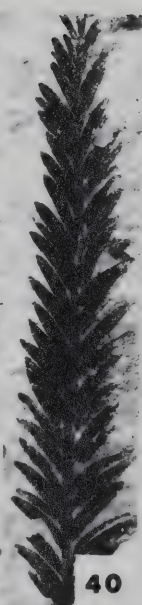
(Collected from Genesee, Alberta).



38



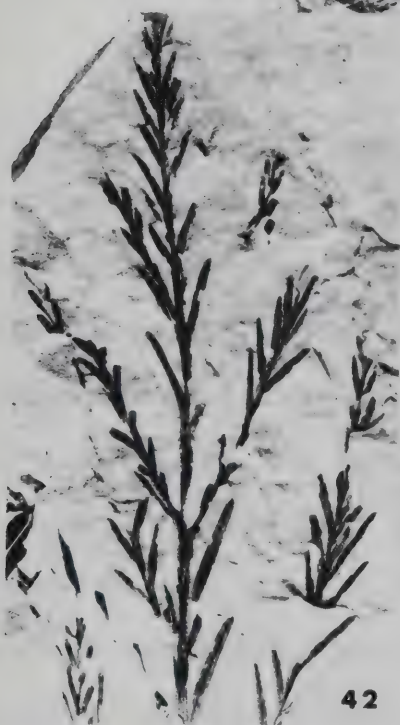
39



40



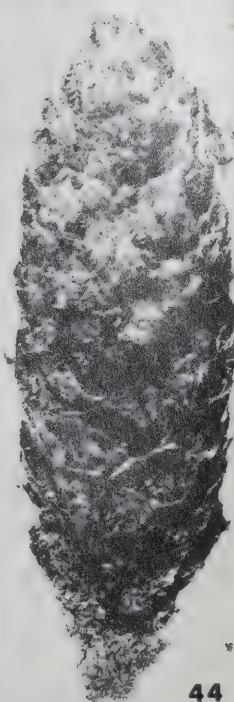
41



42



43



44

in the figure.

The familial affinities of the cone are unknown at present.

(Figured specimen bearing the number S 2837 was collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta).

Class: ANGIOSPERMAE

Sub-class: Monocotyledonae

Family: Lemnaceae

Spirodela scutata Dawson

(Pl. 2, figs. 8, 9)

Comment: Ten specimens were recovered from the Genesee collection. In size, they are on average 18 mm wide and 15 mm long. The plant body is a thin flat thallus, sub-orbicular with about 14 arcuate veins radiating from a common point at the base. The veins converge distally. A pattern of equidimensional polygonal or circular areas with diameters of 350 μ is seen between the veins in some specimens (pl. 2, fig. 9). Bell (1949) suggested that this pattern may represent aerenchyma. A similar pattern was observed in the living *Spirodela polyrrhiza* (L.) Schleiden. Specimens collected from Genesee exhibit carbonized remains of pubescence on the surface, a fact also recorded by Bell in one of his specimens (1949). The Genesee specimens bear a close resemblance to some of the specimens described and figured by Bell (1949, p. 82, pl. 63, fig. 3) and are made

conspecific with *Spirodela scutata* Dawson. Brown (1962) treated Bell's (1949) specimens as synonymous with *Hydromystria expansa* (Heer) Hantke. However, Brown admitted that the assignment to *Hydromystria* was not completely appropriate. Ward's (1887, p. 17, pl. 3, figs. 4,5) *Lemna scutata* Dawson can be favourably compared to the Genesee specimens.

In the Genesee collection *Spirodela scutata* Dawson is invariably associated with the floating aquatic fern *Azolla schopfi* Dijkstra.

Bell reports the occurrence of *Spirodela scutata* from Paleocene beds.

(Figured specimens bearing numbers S 944 and S 824, were collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta).

Sub-class: Dicotyledonae

Family: Cercidiphyllaceae

Genus: *Cercidiphyllum* Sieb. & Zucc.

Introduction: Brown (1935, 1939, 1962) made the first major contribution in delimiting the specific status of the fossil leaves of *Cercidiphyllum*. In attempting to resolve "a 70 year old problem" (Brown, 1939, p. 485) he synthesized numerous uppermost Cretaceous and Tertiary species, assigned at that time to such diverse genera as *Populus*, *Zizyphus*, *Smilax*, *Ficus* etc., into five stratigraphically separated species of *Cercidiphyllum*. The five species are, *C. ellipticum* (Newberry) Brown., (lowest Upper Cretaceous

into Paleocene); *C. arcticum* (Heer) Brown., (Paleocene to middle Eocene); *C. elongatum* Brown., (middle or late Eocene to probable upper Oligocene or lowest Miocene); *C. crenatum* (Unger) Brown., (upper Oligocene to late Miocene); and *C. japonicum* Siebold and Zuccarini (originated in late Miocene or Pliocene and surviving at present). Brown's (1939) synthesis was intended to serve a two-fold purpose; first, to erect nominal and recognizable species and second, to trace a stratigraphic and morphological evolution of the species from its earliest occurrence to the present day. A significant adjunct to Brown's (1939) study of the fossil leaves, was the discovery of fruits and seeds associated with the leaves, and the inclusion of them in his specific designations. The recognition of a strong resemblance of a number of fossil leaves to *Cercidiphyllum* did not originate with Brown (1935, 1939). As early as 1877, Heer noted the similarity between *Cercidiphyllum japonicum* Sieb. and Zucc. in his description of *Grewia crenata* (as quoted in Seward and Conway, 1935, p. 15). Berry (1922) first proposed the form genus *Trochodendroides* under the family Trochodendra-ceae to include fossil leaves resembling *Cercidiphyllum*. Brown (1939) put forth tenable reasons for replacing the name *Trochodendroides* by *Cercidiphyllum*, one of the reasons being to remove the ambiguity that *Trochodendroides* resembles *Trochodendron*, the living Asiatic genus. It should, however, be noted that Berry himself (1922, 1926, 1930, 1935) acknowledged the fact that *Trochodendroides* does not

resemble *Trochodendron*. A significant publication which deserves to be mentioned in this context was by Swamy and Bailey (1949) in which the morphological and taxonomic affinities of *Cercidiphyllum* were thoroughly discussed. These authors came to the conclusion that the genus *Cercidiphyllum* could not be included in Trochodendraceae or any other family and they suggest that it should be raised to a familial status of its own. This conclusion in effect lends support to Brown's (1939) substitution of *Cercidiphyllum* in the place of *Trochodendroides*. A major reshuffling of *Cercidiphyllum arcticum* (Heer) Brown (Brown, 1939) was made by Wolfe (1966). On the basis of the nature of ultimate venation, which he considered to be a criterion for specific and supra-specific designation, Wolfe (1966) recognized five species in the *C. arcticum* (Heer) Brown assemblage. As a consequence new combinations were erected (Wolfe, 1966) and some of the species originally listed by Brown (1939, 1962) under *C. arcticum* were transferred variously to *Cocculus flabella* (Newberry) Wolfe, *Trochodendroides serrulata* (Ward) Wolfe, and *Dicotylophyllum richardsoni* (Heer) Wolfe. It was also noted by Wolfe (1966, p. B 9) that his revision of *Cercidiphyllum* "is not yet completed".

Irrespective of the merits of the situation thus far, the fact remains, that none of the workers who dealt with the foliar morphology and variation of *Cercidiphyllum* either exclusively (Brown, 1935, 1939) or incidentally (Lindquist, 1954; Swamy and Bailey, 1949; Seward and Conway, 1935;

Wolfe, 1966; Harms, 1916; Harms, 1918) seems to have studied foliar variation within the genus critically, in great detail and on a large scale. If they did, it is not apparent from the information given in their publications. It should, however, be mentioned that Brown (1935, 1939) did point out in a general way the diversity of leaf form in *Cercidiphyllum*. He also showed how *Cercidiphyllum* could be distinguished from *Populus* and *Grewia*. One of the features he took into consideration was the presence of acropetiolar glands in *Populus* and their absence in *Cercidiphyllum*. Many details, however, relating to variation in gland placement on the margin, marginal configuration and minor venation, were not treated in his article. A critical study of these and other characteristics thus became a necessity in view of the abundant well-preserved material (nearly 45% of the collection) recovered from Genesee fossil beds. The present detailed study of the foliar morphology of the extant *Cercidiphyllum* was undertaken to evaluate the morphological and anatomical range of variability in quantitative terms and provide a satisfactory basis for comparison with the fossil leaves. Where quantitative data failed to resolve a problem in the identification of a fossil leaf, recourse was taken in the diagnostic qualitative features which could not be reduced to quantitative terms.

Modern *Cercidiphyllum* occurs as two temperate Asiatic species and one variety viz., *C. japonicum* Sieb. and Zucc., *C. magnificum* (Nakai) Nakai (Lindquist, 1954; Ohwi, 1965),

and *C. japonicum* var. *sinense* Rehd. and Wils. (Seward and Conway, 1935). Both species of *Cercidiphyllum* bear dimorphic shoots, long shoots and short shoots, the long shoot bearing polymorphic leaves. In addition, in *Cercidiphyllum japonicum*, sucker or sprout shoots develop adventitiously from the base of the trunk. (Personal observation at the Arnold Arboretum and the New York Botanic Garden). Information is lacking on this aspect for *C. magnificum* and *C. japonicum* var. *sinense*, but presumably they also bear sucker shoots. While a superficial similarity could be observed between the short shoot leaves of *C. japonicum* and *C. magnificum*, there is a considerable difference between the long shoot leaves of the two species. For the sake of clarity the foliar organization in each species is described separately below:

Cercidiphyllum japonicum:

Short shoot leaves: (pl. 9, figs. 58 to 60, 61, 63 to 65; pl. 11, figs. 72, 79; pl. 12, fig. 84).

Petiolate; texture normally chartaceous, rarely coriaceous; shape variable cordate to broadly ovate; margin crenate-serrate, crenate, slightly irregular in shape with 3 to 4 crenations per cm, gland-tipped, sinuses angular or rounded; glands normally apical in position, but occasionally near the sinus. Nature of dentition variable with rounded-serrate teeth at the base of the leaf grading into crenate teeth (pl. 11, fig. 79). Leaf tip retuse with a gland in the notch (pl. 8, fig. 52). Major venation (pl. 11, fig. 72) palmate, midrib straight up to the point of origin of

the first strong secondary, zig zag for the rest of its length (pl. 9, fig. 65). Three pairs of primary veins flanking the midrib basal in origin, inner primaries strongest outer primaries weakest. First strong secondary veins from the midrib originate at a point above the maximum width of the leaf, opposite or alternate. Inner pair of primaries proximally straight, distally zig zag, divergent, ascending almost reaching the margin. Inner primaries join the first strong secondaries of the midrib forming loops. All the secondaries originating from the midrib above the strong secondaries form successive loops with each other. Weak secondary veins originating from midrib, below the strong secondary percurrent, zig zag. Basal-most outer secondary veins originating from inner primaries opposite or alternate; outer secondaries from the inner primaries forming angular loops with each other. Middle primaries zig zag, curve upward to join the first outer secondaries of the inner primaries forming angular loops. Outer primaries form angular loops with the first outer secondaries of the middle primaries. Outer secondaries of the middle primaries form angular loops with each other; outer tertiaries from the outer primaries form angular loops extending branches to the marginal glands. Each gland is normally provided with a single veinlet. Vein islets polygonal often irregular intruded by freely branching veinlets (pl. 12, fig. 84); veinlets terminate in one or more tracheids.

Comment: In addition to the morphological features

described above, some of the leaves exhibit a marked bilateral asymmetry in laminar organization.

Long shoot leaves: (pl. 8, figs. 45 to 49, 56, 57; pl. 11, fig. 77; pl. 12, fig. 82)

Texture chartaceous or coriaceous; petiolate; shape elliptic to ovate, leaf tip acute, acuminate or retuse, gland-tipped (pl. 8, fig. 51), leaf base cuneate, or rounded obtuse or truncate; leaf margin serrate or rounded serrate, serrate-crenate, or glandular-entire; glands normally apical on the teeth, sometimes in the sinuses; frequency of dentition 1.5 to 4.0 teeth per cm with a mean of 2 teeth per cm. Fundamental organization of venation resembles short shoot leaves; palmate, zig zag with a straight midrib, flanked by two pairs of primaries; the first strong secondaries from the midrib originate distally well above the widest portion of the leaf, alternate or opposite straight or curved; strong secondaries and weaker secondaries above them form successive loops with each other; inner pair of primaries ascending, straight or arcuate or sometimes divergent, joining with the first strong secondaries of the midrib to form loops; inner primaries normally basal, occasionally suprabasal in origin; first outer secondaries arising from the innermost primaries generally alternate, occasionally opposite; all the outer secondaries arising from the inner primary including the first outer secondary, form loops with each other; outer primaries ascending, zig

zag, joining and forming angular loops with the first outer secondary of the inner primaries; outer secondaries of the outer primaries, zig zag, forming loops with each other as well as with the outer tertiaries of the outer secondary loops of the inner primary; outermost loops near the margin extend branches to the marginal glands; each gland is provided with a single veinlet. Vein islets polygonal or irregular, intruded by ramified veinlets (pl. 12, fig. 82).

Sucker shoot leaves: (pl. 8, figs. 50, 53; pl. 9, fig. 62; pl. 11, figs. 73 to 76, 78; pl. 12, fig. 83)

Sucker shoot leaves show a strong similarity to long shoot leaves in shape, margin and organization of the venation; but in a number of instances their morphology is intermediate between short shoot and long shoot leaves. In size, sucker shoot leaves are larger than the long shoot leaves, with a wider range; shape ovate; leaf tip acute or acuminate, gland-tipped; margin glandular-entire, serrate, serrate-crenate or crenate; glands apical on teeth or in sinuses (pl. 11, figs. 74, 76, 78); frequency of teeth per cm highly variable, with a mean of 3 teeth per cm. Leaf base incipient cordate or cordate; organization of venation similar to that described for long shoot leaves above. A detailed description, therefore, is not attempted here but for a few exceptions. In long shoot leaves the number of pairs of primaries is typically two, while in sucker shoots three pairs of primaries are common. Outer primaries are

the weakest. The outermost pair of primaries form loops as in short shoot leaves. The innermost pair of primaries are ascending, parallel to the midrib (pl. 9, fig. 62) or arcuate (pl. 8, fig. 50; pl. 11, fig. 73) or divergent (pl. 11, fig. 75).

Seedling leaves: (pl. 8, figs. 54, 55)

Seedling leaves resemble sucker leaves in foliar morphology.

Comment: Although the various types of leaves described above bear some common features, a few significant points need to be emphasized:

1. The consistent basal origin of the inner primaries; constant presence of cordate base and absence of glandular-entire margin in short shoot leaves.
2. The consistent absence of cordate base in long shoot leaves.
3. The intermediate nature of sucker shoot and seedling leaves between long shoot and short shoot leaves with more features in common with long shoot leaves.
4. A consistent correlation between the nature of the base and the presence of an extra pair of outer primaries, i.e., long shoot leaves with truncate base show only two pairs of primaries, while sucker shoot leaves, resembling long shoot leaves in all other features except the cordate base, show three pairs of primaries.

Cercidiphyllum magnificum:

Short shoot leaves: (pl. 10, fig. 67; pl. 11, fig. 81; pl. 12, figs. 85, 86)

Foliar morphology is closely similar on a qualitative basis to *C. japonicum* but for the margin, gland placement on the margin and the course of the inner primaries. In *C. magnificum* the margin is deeply crenate, sometimes irregular, glands always apical on teeth (pl. 11, fig. 81) and the base is deeply cordate or rarely auriculate. The course of the innermost pair of primaries is nearly parallel to the midrib, whereas in *C. japonicum* they are divergent.

Long shoot leaves: (pl. 10, figs. 66, 68, 69 to 71; pl. 11, fig. 80; pl. 12, fig. 87)

Petiolate; texture chartaceous; shape elliptic or ovate; leaf tip generally retuse with a gland in the notch; margin deeply serrate, rounded serrate, crenate, dentate (pl. 10, fig. 71, see distal teeth to the left) or irregular, gland-tipped, with variable frequency of 1 to 3 teeth per cm; glands usually apical, very rarely in sinuses, sinuses angular (pl. 11, fig. 80); leaf base truncate to incipient cordate. Venation is similar to the long shoot leaves of *C. japonicum*, in general organization, except for the number of pairs of primaries; primaries generally two pairs but in leaves with incipient cordate base three pairs are seen. Inner primaries are divergent or parallel. Secondary and tertiary looping is identical to the long shoot leaves of

C. japonicum in organization.

Comment: In *C. japonicum* branches bearing long shoots and short shoots, show a clear cut distinction between long and short shoot leaves, in some features. On the other hand, in *C. magnificum* the distinction between long shoot leaves and short shoot leaves, in many cases, is not pronounced.

Leaves of *C. japonicum*, irrespective of geographical location and age of the plant, type of leaf, i.e., whether long shoot, short shoot or sucker shoot leaf, show at least one consistent anatomical feature viz., the presence of highly lacunose spongy mesophyll (pl. 12, figs. 82 to 84). The lacunae represent intercellular spaces. This feature is also observed in *C. magnificum* (pl. 12, figs. 86, 87). The lacunae are visible even in uncleared leaves when viewed under transmitted light at a magnification as low as 6X. Of course, they are best seen in cleared and stained leaves. In cleared and stained leaves the spongy mesophyll gives the appearance of aerenchyma. The lacunae are regular in organization, usually circular in outline with variable diameter of 40 μ to 100 μ . A significant observation was the relative smaller size of the lacunae in short shoot leaves (pl. 12, fig. 84), with a mean diameter of 45 μ , compared to long shoot leaves in which the mean diameter was 80 μ (pl. 12, fig. 82). The lacunae are uniform in *C. magnificum* and have a mean diameter of 45 μ in both short and long shoot leaves. Thus, the difference in size of the lacunae between short and long shoot leaves in *C. magnificum* is less

Plate 8.

- Figs. 45-57. *Cercidiphyllum japonicum* Sieb. and Zucc.
- Figs. 45-49. Long shoot leaves. X 0.8.
- Fig. 50. Sucker shoot leaf with suprabasal inner primaries indicated by the arrow. X 0.8.
- Fig. 51. Apical portion of long shoot leaf with an acute tip. Arrow points to gland. X 8.
- Fig. 52. Apical portion of short shoot leaf with retuse tip. Arrow points to gland in the notch. X 8.
- Fig. 53. Sucker shoot leaf with basal inner primaries indicated by the arrow. X 0.8.
- Figs. 54,55. Seedling leaves. X 0.8.
- Figs. 56,57. Long shoot leaves. X 0.8.



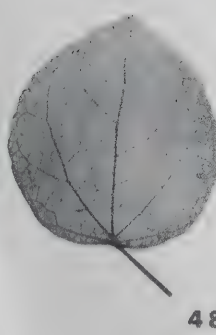
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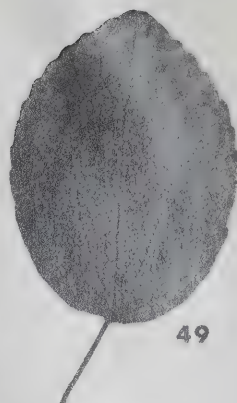
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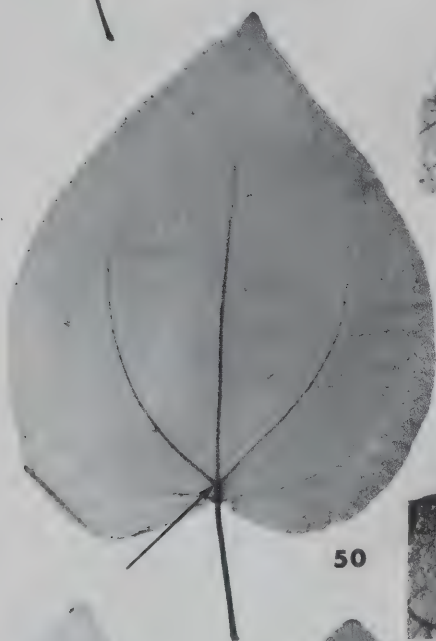
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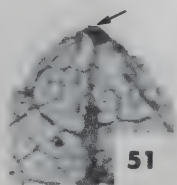
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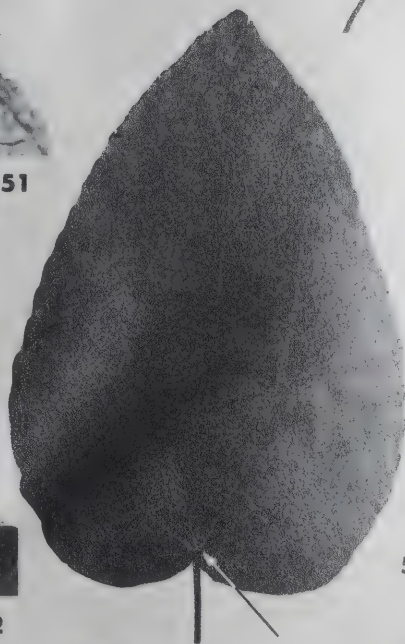
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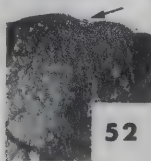
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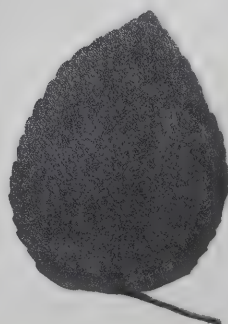
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Plate 9.

Figs. 58-65. *Cercidiphyllum japonicum* Sieb. and Zucc.

Figs. 58-61. Short shoot leaves. X 0.9.

Fig. 62. Sucker shoot leaf. X 0.9.

Figs. 63-65. Short shoot leaves. X 0.9.

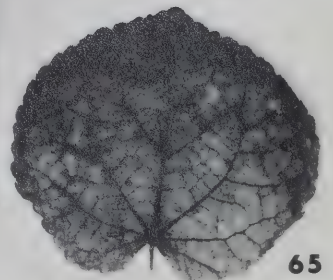
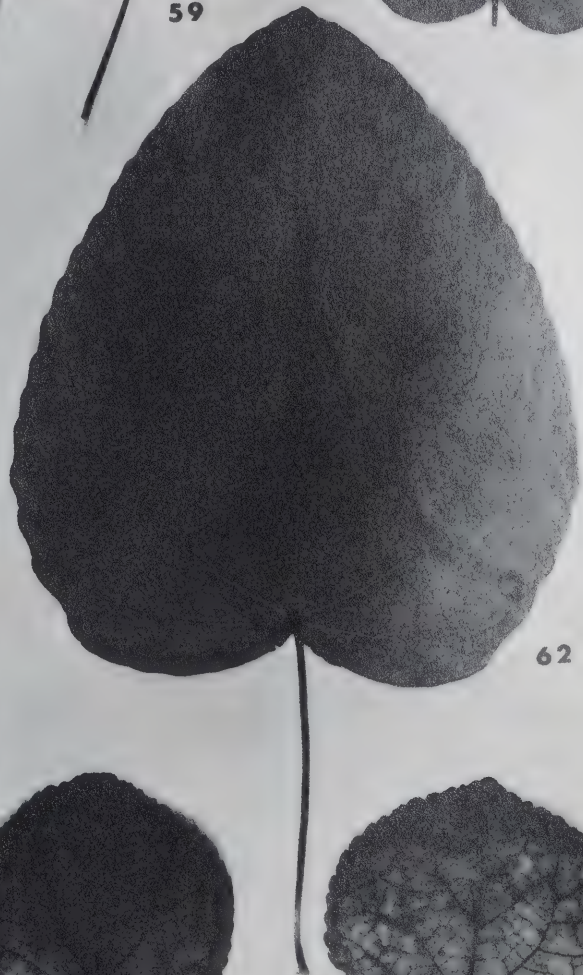
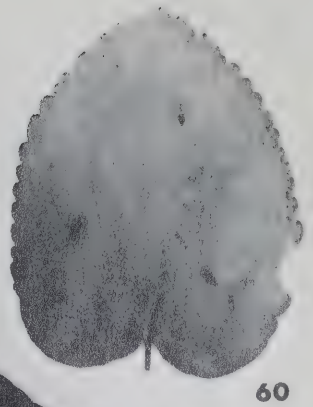
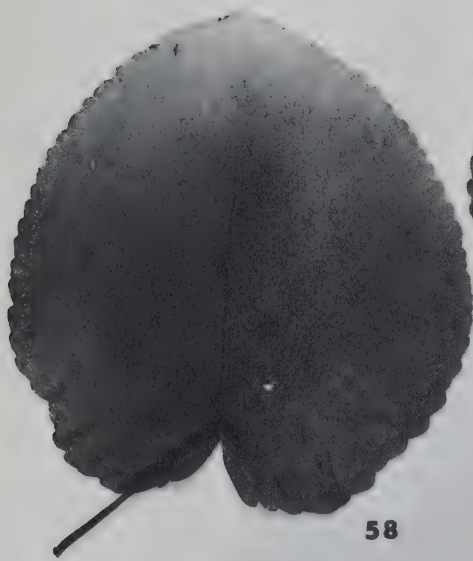


Plate 10.

Figs. 66-71. *Cercidiphyllum magnificum* (Nakai) Nakai.

Fig. 66. Long shoot leaf. X 0.8.

Fig. 67. Short shoot leaf. X 0.8.

Figs. 68-71. Long shoot leaves. Note irregular dentition.
X 0.8.



66



68



67



69



70



71

Plate 11.

- Figs. 72-79. *Cercidiphyllum japonicum* Sieb. and Zucc.
- Fig. 72. Short shoot leaf. ip=inner primary veins; mp=middle primary veins; mr=midrib; op=outer primary veins; os=outer secondary veins; ss=strong secondary veins; ws=weak secondary veins. (Slide #49) X 1.4.
- Fig. 73. Sucker shoot leaf with glandular-entire margin. (Slide # 33) X 1.4.
- Fig. 74. Portion of sucker shoot leaf margin with irregular gland-placement. Arrow points to gland. sn=sinus. (Slide # 33) X 11.
- Fig. 75. Sucker shoot leaf with glandular-entire margin. (Slide # 35) X 1.4.
- Fig. 76. Portion of sucker shoot leaf margin with transitional gland-placement. (Slide # 37) X 9.
- Fig. 77. Portion of long shoot leaf with serrate margin. (Slide # 45) X 9.
- Fig. 78. Portion of sucker shoot leaf with glandular-entire margin. (Slide # 42) X 11.
- Fig. 79. Portion of short shoot leaf with transitional, rounded serrate to crenate, dentition. Note variable gland-placement. (Slide # 48) X 7.
- Fig. 80. *Cercidiphyllum magnificum* (Nakai) Nakai. Portion of long shoot leaf margin with serrate teeth and apical glands. (Slide # 61) X 11.
- Fig. 81. *Cercidiphyllum magnificum*. Portion of short shoot leaf margin with crenate teeth and apical glands. (Slide # 58) X 11.

PLATE 11

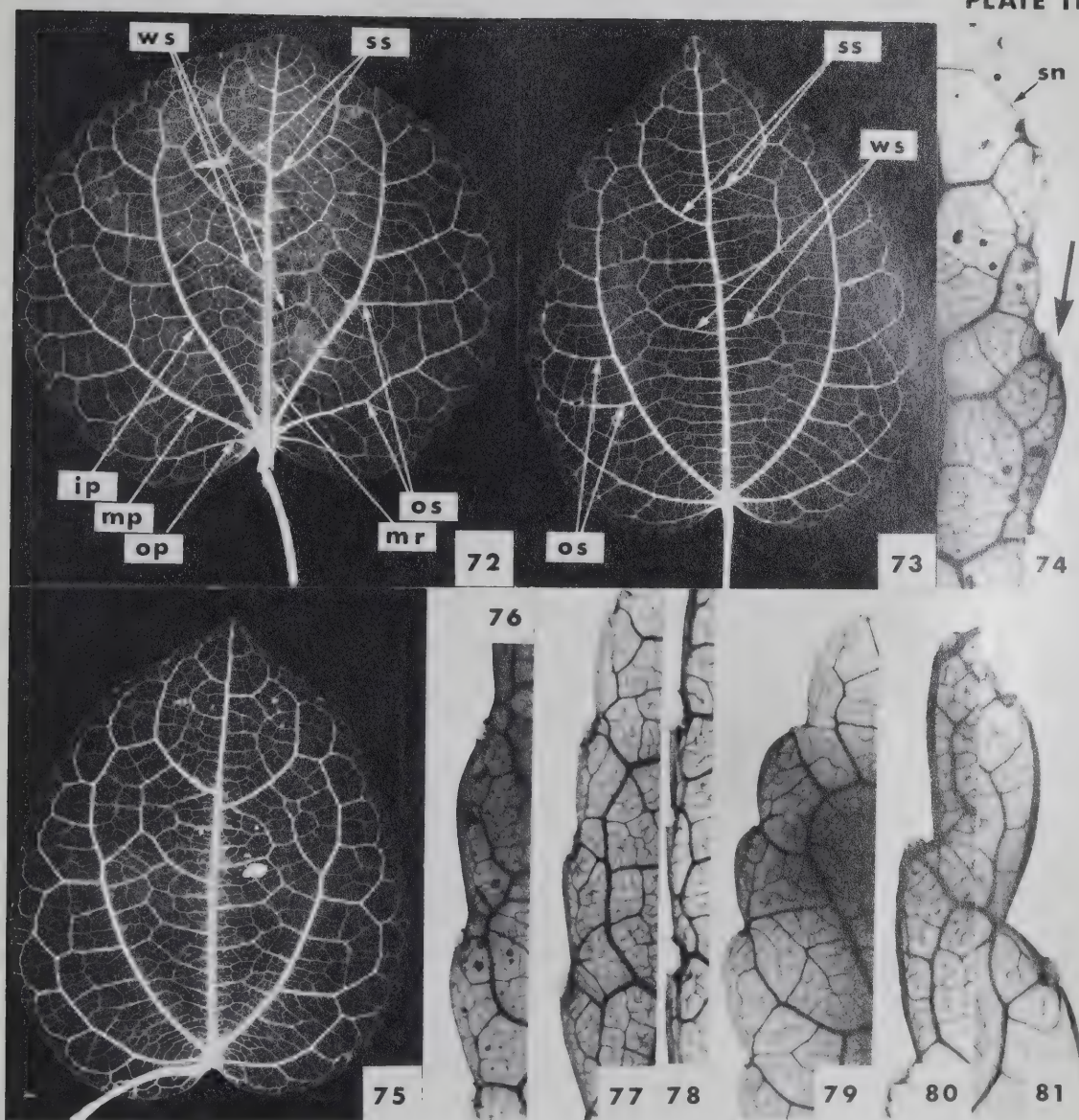


Plate 12.

Figs. 82-84. *Cercidiphyllum japonicum* Sieb. and Zucc.

Fig. 82. Portion of a cleared long shoot leaf with lacunose mesophyll, irregular vein islets and branched veinlets. (Slide # 27) X 22.

Fig. 83. Portion of a cleared sucker shoot leaf with thick, branched veinlets. (Slide # 42) X 22.

Fig. 84. Portion of a cleared short shoot leaf with small mesophyll lacunae. (Slide # 26) X 22.

Figs. 85-87. *Cercidiphyllum magnificum* (Nakai) Nakai.

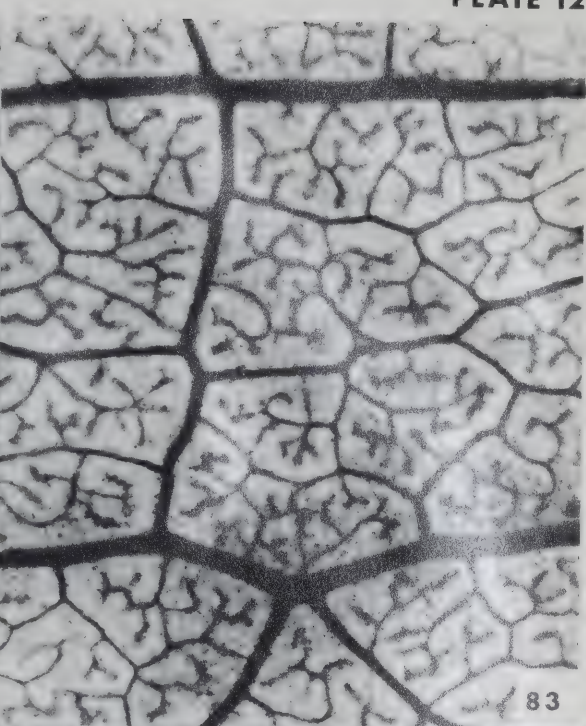
Fig. 85. Portion of a cleared short shoot leaf.
(Slide # 56) X 11.

Fig. 86. Portion of a cleared short shoot leaf. Note simple veinlets intruding vein islets.
(Slide # 58) X 11.

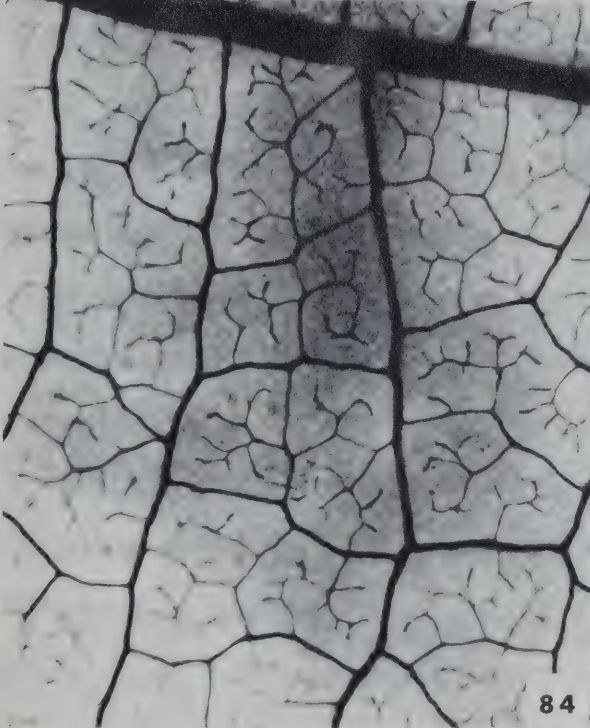
Fig. 87. Portion of a cleared long shoot leaf.
(Slide # 61) X 11.



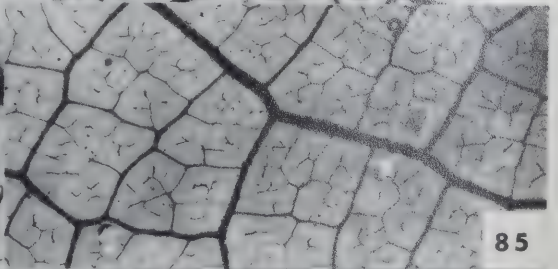
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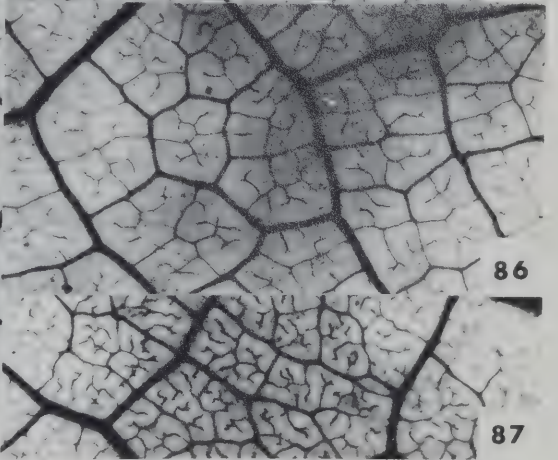
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87

than in *C. japonicum*.

Statistical analysis:

It should be made clear at the outset that statistical analysis as applied here makes no pretense of solving taxonomic problems decisively. What it does is to give more credibility to taxonomic generalizations and to assist, in a limited way, in the identification of fossil leaves.

The two species of *Cercidiphyllum* show a high degree of resemblance in foliar morphology that is noticeable in all aspects of the leaf, i.e., in form, major and minor venation and marginal configuration. To explore the possibility of distinguishing the two species and apply the information thus gained to the fossils suspected to belong to the genus *Cercidiphyllum*, a statistical treatment was devised to assign limits of variation for the genus. The distinction of leaves as long shoot and short shoot leaves is ignored. This distinction though relevant in living species is meaningless as applied to fossils, since there is no way of ascertaining whether the fossils belonged to long shoots or short shoots or whether such a distinction existed in the remote past.

Four hundred leaves of both species of *Cercidiphyllum* including sixty-five cleared and stained leaves were analyzed with respect to major and minor venation, and the ratio of length to width. The leaves were obtained from different plants from various geographical localities. Seven characteristics were arbitrarily chosen. These are: the angle between the inner primary veins, termed the primary angle;

the mean adaxial angle between the weak secondary veins and the midrib measured at the widest portion of the leaf, termed the weak secondary angle; the mean adaxial angle between the first strong secondary vein and the midrib, termed the strong secondary angle; the mean adaxial angle between the first two outer secondary veins of the inner primaries and the inner primaries, termed the outer secondary angle; ratio of length to width termed the L/W ratio; the mean number of vein islets per square mm measured at random within areas midway between the midrib and margin at the widest portion of the leaf, termed the vein islet number; the mean number of freely ending veinlets per square mm counted at random within areas midway between the midrib and margin at the widest portion of the leaf, termed the veinlet termination number. Vein islets and veinlet terminations were counted in cleared leaves.

From the data obtained (Tables 1 to 11, appendix) and presented (graphs 1 to 5, appendix), the following observations are made:

1. That *Cercidiphyllum* as a genus has a wide variability in all the aspects considered.
2. That the primary angle and L/W ratio are not good criteria for specific designation.
3. That the weak secondary angle, the outer secondary angle and the strong secondary angle are of some value in distinguishing the two species, because of the distinct peaks observed.

4. That with respect to vein concentration per unit area, expressed as vein islet number and veinlet termination number, a number of inferences could be drawn (Tables 9 to 11). These are: (a) no correlation exists between the vein islet number and the corresponding veinlet termination number; (b) over-all variation within the species, with respect to vein islet number and veinlet termination number as observed in *C. japonicum*, is not marked and is independent of geographical location and the type of leaf (Table 9); (c) sucker shoot leaves have a lower mean vein islet number compared to short shoot and long shoot leaves if geographical location is disregarded (Table 9); (d) in *C. magnificum* the over-all mean vein islet number is significantly higher than in *C. japonicum* (Table 11); (e) no difference is observed in the mean veinlet termination number between the two species (Table 11); (f) in *C. magnificum*, (Table 10, slide numbers 55 and 60), a relationship is seen between the small size of the leaf and high vein islet number, the probable inference being that the vein islet number is dependent upon the relative maturity of the leaf. Some of the conclusions have a direct bearing in the identification of fossil leaves.

To summarise, the foliar morphology of the genus *Cercidiphyllum* exhibits a number of features, qualitative and quantative, which are characterized below:

1. Elliptic, ovate or cordate shape, the range of L/W ratio being 0.7 to 2.0.

2. Acute or acuminate or retuse tip invariably terminated by a gland, either at the tip or in the notch, when retuse.
3. Cuneate, rounded obtuse, truncate or cordate base.
4. Glandular-entire, serrate, crenate, rounded serrate or serrate-crenate margin; sinuses angular or rounded; shape of crenations regular or irregular; glands apical on the teeth or in sinuses; glands emergent or non-emergent.
5. A progressive obliteration of marginal configuration as observed on the same leaf, starting from a crenate margin near the base grading into a glandular-entire margin distally.
6. Venation zig zag, palmate with a straight or partly straight and partly zig zag midrib flanked by two or three pairs of primary veins; inner primary angle with a range of 40 to 105°; inner primaries strongest; primaries basal or suprabasal in origin; course of inner primaries divergent, arcuate or nearly parallel to midrib; first strong secondaries arising from the midrib, distal, alternate or opposite, straight or curved well above the widest portion of the leaf with a range of 40 to 75°; weak secondaries arising from the midrib showing a range of 40 to 90°; outer secondaries arising from inner primaries showing a range of 40 to 90°; secondaries of the midrib, outer secondaries of primaries showing angular marginal looping; vein islets regular or irregular intruded by simple to highly branched veinlets; vein islet number showing a range of 0.4 to 5.5; veinlet

termination number showing a range of 5 to 30.

7. Presence of highly lacunose spongy mesophyll with a range of 40 μ to 100 μ , in diameter.

It should be emphasized that none of the foregoing characters when taken alone is of any diagnostic value. Sometimes a character may be so similar in both species that it loses value as a taxonomic character. For example, the strong secondary angle in *C. japonicum* and *C. magnificum* shows highest frequencies at 50° (graph 3). This means that this character is of no value in separating the two species. So one must look for other distinguishing characters. As applied to fossils, however, the same character (the strong secondary angle) is of some value in distinguishing species (graph 3).

A similar statistical treatment was given to 435 fossil leaves which were tentatively assigned to *Cercidiphyllum*, based on qualitative features. The analysis was done with a two-fold purpose. First to give precision in describing the species and second to compare and evaluate the characters against those of the living species. On the basis of the totality of characters, qualitative as well as quantitative, the assemblage of fossils falls into three species under the genus *Cercidiphyllum*, viz., *C. genesevianum* sp. nov., *C. flexuosum* (Hollick) n. comb., *C. cuneatum* (Newberry) n. comb.. In spite of the excellent preservation no recognizable cuticular remains could be recovered. Some of the compressions show brownish areas, which after maceration failed to

reveal any structural detail. A common but unique feature observed in all well-preserved specimens are circular lacunae which occur in patches (pl. 13, figs. 90, 92; pl. 16, figs. 116, 117; pl. 17, fig. 121; pl. 19, fig. 129; pl. 22, fig. 151; pl. 23, fig. 156; pl. 24, fig. 166; pl. 25, figs. 171, 172; pl. 26, fig. 174; pl. 27, figs. 184, 187; pl. 28, figs. 193, 194; pl. 29, fig. 197). The lacunae are easily observed even under low magnification. In size, the lacunae show a wide range of variation. Based on fifty random measurements in ten specimens the lacunae show a mean diameter of 75 μ . A comparison of the lacunae with the intercellular spaces in the spongy mesophyll tissue, already described, in cleared leaves of *Cercidiphyllum* (compare pl. 12, fig. 82 and pl. 16, fig. 117) showed a remarkable morphological similarity. Epidermal cells in the extant species of *Cercidiphyllum* are roughly square to rectangular in shape, small in size, having wavy cell walls. These cells are in no way comparable to the lacunae found in the fossils, thus eliminating the possibility that the lacunae might represent the intracellular spaces of epidermal cells. Further, it has been observed in transverse sections of a number of thin leaves of *Cercidiphyllum japonicum* Sieb. and Zucc., that the palisade mesophyll tissue is poorly developed consisting of short, thin-walled, small cells with a mean diameter of 10 μ and having small intercellular spaces. Intracellular spaces of epidermal as well as palisade cells and intercellular spaces in the palisade tissue are too small to be comparable

with the lacunae observed in the fossils, thus eliminating the possibility that the lacunae might be the remains of either epidermal or palisade tissue. These observations support the conclusion that the lacunae observed in the fossil leaves are indeed intercellular spaces of spongy mesophyll and cannot be intra- or intercellular spaces in other tissues of the leaf. For descriptive purposes the lacunae, observed in the fossils, are termed mesophyll-configurations. Similar mesophyll-configurations, smaller in size, were also observed in a few specimens of *Platanus raynoldsii* Newberry and one specimen of *Ampelopsis acerifolia* (Newberry) Brown. Taken in conjunction with other characteristics the patterns of mesophyll-configurations were found to be valuable as an additional aid in identification.

The term 'glands' in the descriptions to follow is used in a descriptive sense. These structures are in fact carbonized dark masses occupying an analogous position in comparison with the living counterparts.

Cercidiphyllum genesevianum sp. nov.

(Pl. 13, figs. 88 to 95; pl. 14, figs. 96, 99 to 106; pl. 15, figs. 107 to 111, pl. 16, figs. 112 to 117; pl. 17, figs. 118 to 121; pl. 18, figs. 122 to 125; pl. 19, figs. 126 to 131). (Tables 12 to 14 append., graphs 1 to 5)

Diagnosis: Texture chartaceous, very rarely coriaceous; petiolate; shape, narrow ovate, ovate, very wide ovate, with a mean L/W ratio of 1.4 and a range of 1.0 to 2.0; leaf tip

acute, acuminate, attenuate, gland-tipped; margin glandular-entire, serrate, rounded serrate, serrate-crenate, finely crenate, with a mean of 3 teeth per cm, and a range of 2 to 6 per cm; sinuses angular, rounded; gland placement on the margin, apical on the teeth, in sinuses or apical grading into a sinus position on the same leaf; glands prominent, emergent, non-emergent; base rounded obtuse, truncate or cordate; major venation palmate, zig zag, midrib straight, flanked by 2 or 3 pairs of primaries, inner primaries strongest, basal or suprabasal in origin, proximally straight up to the origin of the first outer secondary, ascending, parallel with the midrib or arcuate at the widest portion of the lamina, curving towards the midrib distally, above the widest portion of the lamina with a mean primary angle of 68° and a range of 45 to 105° ; first strong secondaries arising from the midrib, distal, conspicuous or inconspicuous well above the widest portion of lamina, opposite or alternate; superadjacent secondaries originating from midrib above the strong secondaries, camptodromous forming successive loops with each other as well as with the strong secondaries; mean strong secondary angle, when strong secondaries are conspicuous, is 61° with a range of 45 to 75° ; inner primaries join first strong secondaries of the midrib when the latter are conspicuous forming angular loops; weak secondaries subjacent to the strong secondaries, arising from the midrib, with a mean weak secondary angle of 73° and a range of 55 to 90° ; basal-most outer secondaries arising from inner primaries,

alternate, zig zag, craspedo-camptodrome, with a mean outer secondary angle of 70° and a range of 45 to 90° . Outer secondaries of inner primaries forming angular loops with each other; middle primaries, where 3 pairs of primaries present, basal, zig zag, craspedo-camptodrome joining the basal-most outer secondaries of the inner primaries, forming angular loops; outer-most primaries, weakest, basal, zig zag, craspedo-camptodrome joining the basal-most outer secondaries of the middle primaries when 3 pairs of primaries present, or inner primaries when 2 pairs of primaries present, forming loops; outer branches of secondary loops, forming successive loops with each other, whose outer branches in turn form loops with each other, resulting in tertiary and quaternary angular loops; vein islets polygonal, regular or irregular, intruded by simple or branched veinlets; veinlets of varying thickness; vein islet number with a mean of 1.8 and a range of 0.7 to 6.5; veinlet termination number with a mean of 6 and a range of 4 to 10; a single veinlet from a marginal loop enters a marginal tooth terminating at the base of a gland; mesophyll-configurations show a mean diameter of 75μ .

Comment: The species shows a wide range in every aspect.

Not all specimens exhibit every feature described above. Out of a total of 120 specimens (Table 14) including recognizable fragments, 71 specimens (Table 12) were selected for analysis. Thirty-nine specimens showed good preservation of minor venation (Table 13). Ultimate veinlets which intrude vein islets could not be observed in a number of specimens (Table

13) in areas selected for counting. They were, however, observed in other areas of the lamina. The smallest leaf (pl. 13, fig. 94) was of 120 sq mm, with a length of 18 mm and a width of 10 mm. The largest was of 6020 sq mm with a length of 105 mm and a width of 86 mm (specimen number S 811 from Genesee, Alberta). Margin shows a high degree of variation (pl. 14, figs. 99 to 106). The glands are prominent (pl. 14, figs. 99 to 102, 104 to 106) when they are situated in the sinuses or near the sinuses and not so prominent when they are apically situated on the serrations (pl. 14, fig. 103). A similar range of variation is observed in marginal dentition in *Cercidiphyllum japonicum* (compare pl. 14, fig. 97 with pl. 14, fig. 104. Compare also pl. 14, fig. 98, with pl. 14, figs. 99 to 101, 105, 106). The margin may be serrate in the lower part of the leaf, grading into a glandular-entire or entire margin distally (pl. 16, fig. 112). A number of leaves bear a close resemblance to the leaves of modern *Cercidiphyllum japonicum* in a number of features. For example, some leaves (pl. 15, fig. 108; pl. 19, fig. 126, 131) show similarity to seedling leaves (compare pl. 19, fig. 126 and 131, with pl. 8, figs. 54, and 55); others resemble long shoot leaves (compare pl. 13, figs. 88, 93; pl. 16, fig. 114 with pl. 8, figs. 45, 47) and a few are comparable to the sucker shoot leaves (compare pl. 19, fig. 127 with pl. 8, fig. 50; compare also pl. 19, fig. 130 with pl. 9, fig. 62). An additional feature that is common to *C. genesevianum* and *C. japonicum* is the suprabasal origin of the inner primary

veins (compare pl. 14, fig. 96; pl. 19, fig. 131; pl. 15, fig. 110 with pl. 8, fig. 45, 50; pl. 11, fig. 75). The assemblage included in *C. genesevianum* could be broadly separated into two groups, one with a serrate margin (pl. 15, fig. 111; pl. 16, figs. 114, 115) and the other with a finely crenate margin (pl. 13, fig. 91, 93; pl. 19, fig. 127) in spite of the similarity of the major and minor venation. But there are specimens, where both serrate and crenate margins are seen on the same leaf (pl. 14, fig. 96; arrows to the right indicate the serrate condition and arrow to the left indicates the crenate condition). It has already been noted that *C. genesevianum* bears a close resemblance to the long shoot leaves of *C. japonicum*. The only significant difference between the two seems to be in the veinlet termination number. The mean veinlet termination number in *C. genesevianum* is 6, while the mean veinlet termination number in long and sucker shoot leaves is 15. In terms of morphology, this illustrates the greater degree of branching of the freely ending veinlets in the extant species compared to the sparse branching in the fossil species (pl. 13, fig. 90; pl. 16, figs. 116, 117; pl. 17, fig. 121; pl. 19, figs. 128, 129). It should be noted, however, that this is not a very decisive character, because a number of short shoot leaves of *C. japonicum* (pl. 12, fig. 84) do show a sparse branching and consequently a low veinlet termination number. The similarity of the ultimate venation in *C. genesevianum* and *C. japonicum*, was tested on a quantitative basis by a "t-test" on the vein islet number

between the long shoot leaves of *C. japonicum* and *C. genesevianum*. The difference in the mean vein islet number between the two species was found to be insignificant at 5% level (Table 15, append.). Veinlets intruding vein islets are sometimes thicker at the base thinning out proximally as wispy strands, a feature also observed in *C. japonicum*.

Leaf variants of *C. genesevianum* bear a superficial resemblance to some of the modern species of *Smilax* and *Tetracentron sinense* Oliv. in general form and venation. Living species of *Smilax* like *S. lasioneura* Hook., *S. bracteata* (Presl), *S. stenopetala*, *S. amaurophlebia* Merr., *S. arisanensis* Hay., *S. china* Linn., *S. ferox* Wall., *S. glabra* Roxb., *S. glaucochina*, *S. lanceaefolia* Roxb., *S. hypoglauca*, Benth., *S. microphylla* Wright., *S. menispermoides* D.C., etc., have an entire margin and on this basis alone can be eliminated as possible correlatives of the variants of *C. genesevianum*. Some species of *Smilax* like *S. scobinicaulis* Wright and *S. sieboldii* Miq. show a spinous margin. These spines are minute, irregularly distributed out-growths from the margin. The spines are not vascularized. This condition is in no way comparable to the regular dentition in *C. genesevianum*. The foregoing information on *Smilax* was gathered from a study of herbarium material at the Arnold Arboretum.

Leaves of *Tetracentron sinense* possess palmate venation, serrate margins with glandular tips and acuminate apices. Some of the variants of *C. genesevianum* have apices that are

acuminate to long attenuate (pl. 13, fig. 91; pl. 18, fig. 123), a feature which is not observed in *Cercidiphyllum*. One of the variants also shows a serrate margin (pl. 18, fig. 125) similar to *Tetracentron*. These are exceptional cases and taken in conjunction with other characters they fall within *Cercidiphyllum* and form an integral part of the spectrum of variation found in *C. genesevianum*.

At this point some of the foliar features of *Tetracentron* need to be elaborated. Fifty leaves from various herbarium sheets from the Arnold Arboretum, were statistically analyzed. The study revealed that *Tetracentron* exhibits consistent features such as a serrate margin, a narrow mean inner primary angle of 30° , mean strong secondary angle of 35° and a mean outer secondary angle of 40° . Vein islets were observed to be regular intruded by once or twice branched veinlets. These features set it apart from *Cercidiphyllum*. It was observed by Smith (1945, p. 139) that, "*Tetracentron sinense* is a very stable species..... The available specimens are remarkable for their lack of variation, even the dimensions foliar and floral parts being unusually consistent". Morphological variation in leaf form is less extensive in *Tetracentron*. The range of variability of the leaves of *Tetracentron* does not overlap the dimorphic foliage of *Cercidiphyllum japonicum* (Bailey and Nast, 1945).

A search through the vast literature failed to reveal any species that would meet all the characteristics of *C. genesevianum*. Fossil species like *Grewia crenata* (Ung.)

Heer (Ward, 1887, p. 85, pl. 39, fig. 1), *Paliurus pealei* Ward (Ward, 1887, p. 76, pl. 33, figs. 12 to 14), *Paliurus pulcherrimus* Ward (Berry, 1935, p. 47, pl. 11, figs. 5 to 8, omit synonymy), *Zizyphus serrulatus* Ward (Ward, 1887, p. 73, pl. 33, fig. 3), *Trochodendroides speciosa* (Ward) Berry (Berry, 1930, p. 22, pl. 5, fig. 8; omit synonymy), *Cercidiphyllum arcticum* (Heer) Brown (Brown, 1939, p. 492, pl. 53, fig. 2; pl. 54, figs. 1, 3; pl. 56, fig. 2; omit synonymy), *Cercidiphyllum arcticum* (Heer) Brown (Koch, 1963, p. 47, pl. 16, fig. 2) and *Cercidiphyllum elongatum* Brown (Becker, 1960, p. 106, pl. 29, fig. 4), bear resemblance to some of the variants of *Cercidiphyllum genesevianum* in general form, marginal configuration, and major venation. The leaf variants grouped under *C. genesevianum*, are remarkable for their preservation and their close similarity to the long shoot and sucker shoot leaves of modern *C. japonicum*. Hence, it is felt that this group of fossils deserves a new specific status instead of being thrown into a species erected on a poorly preserved fragment lacking diagnostic characteristics. The specific epithet is given in honour of the fossil locality. Specimen number S 947 (pl. 13, fig. 89) is designated the holotype. All other figured specimens are paratypes.

(Figured specimens bearing numbers, S 307, S 947, S 2849, S 1596 (A), S 1305, S 1316, S 1346, S 883 (A), S 1586 (A), S 340, S 1034, S 229, S 1064, S 997, S 229, S 268, S 300, S 3150, S 938 (B), S 1021, S 408, S 1597, S 1327, S 2850,

Plate 13.

- Figs. 88-95. *Cercidiphyllum genesevianum* sp. nov.. Fig. 88
(S 307) X 2.2. Fig. 89 (S 947) X 1.4.
Fig. 90. Enlarged portion of fig. 89. Note mesophyll-
configurations. X 11.
Fig. 91. (S 2849) X 0.9.
Fig. 92. Enlarged portion of fig. 91 with details of
venation. X 7.
Fig. 93. (S 1596 (A)) X 2.
Fig. 94. (S 1305) X 3.
Fig. 95. Acuminate tip of leaf in fig. 91. X 8.

(Collected from Genesee, Alberta).

PLATE 13

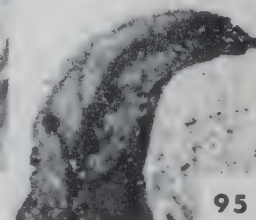
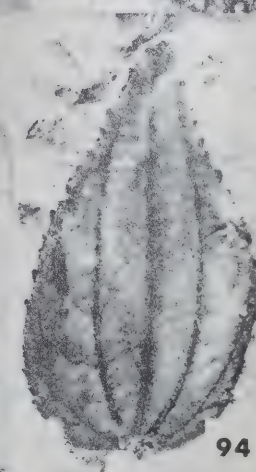
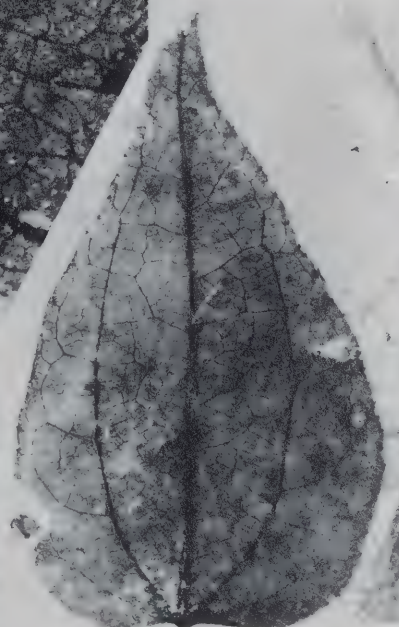
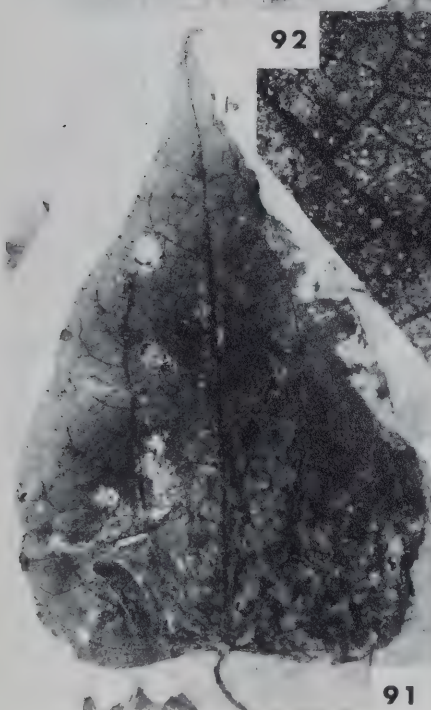
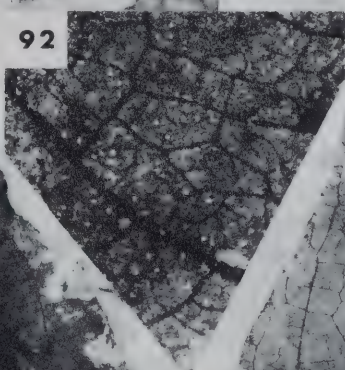
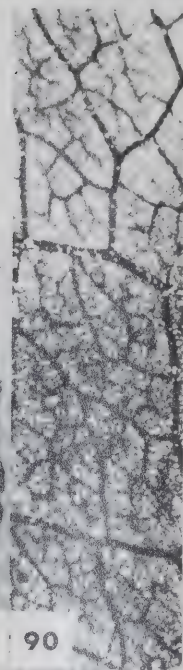
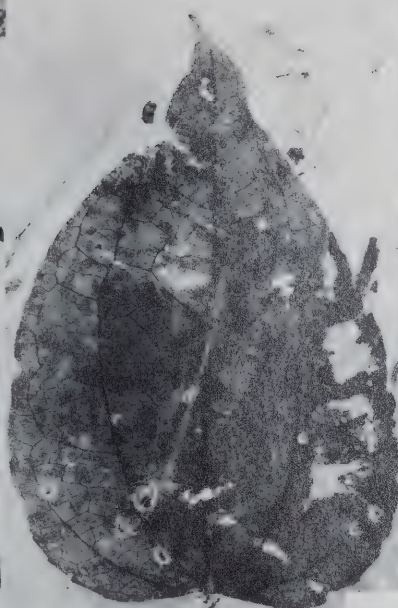
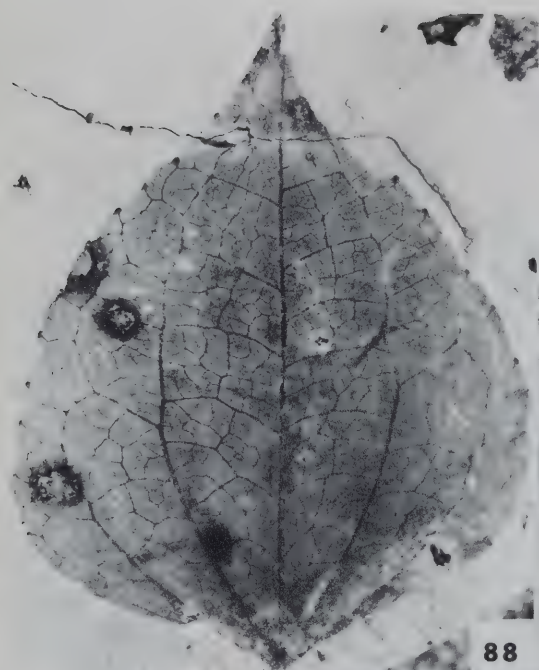


Plate 14.

- Fig. 96. *Cercidiphyllum genesevianum* sp. nov.. Note suprabasal inner primary veins and variation in dentition indicated by arrows. (S 1316) X 2.2.
- Figs. 97,98. *Cercidiphyllum japonicum* Sieb. and Zucc.. Portions of sucker shoot leaf margins for comparison with figs. 99-106. (Slides # 42 and # 32 respectively). X 10.
- Figs. 99-106. *Cercidiphyllum genesevianum* sp. nov.. Portions of leaf margins showing variation in dentition and gland-placement.
- Fig. 99. Transitional gland-placement. sn=sinus. (S 1346) X 10.
- Fig. 100. (S 883 (A)) X 10.
- Fig. 101. (S 1586 (A)) X 10.
- Fig. 102. Note emergent glands. (S 340) X 10.
- Fig. 103. Serrate margin with non-emergent glands. (S 1034) X 10.
- Fig. 104. Glandular-entire margin. Note glands indicated by arrows. (S 229) X 10.
- Fig. 105. (S 1064) X 10.
- Fig. 106. sn=sinus. (S 997) X 10.

(Specimens shown in fig. 96 and figs. 99-106 were collected from Genesee, Alberta).



Plate 15.

Figs. 107-111. *Cercidiphyllum genesevianum* sp. nov.. Note variation in leaf shape and venation.

Fig. 107. (S 1586 (A)) X 1.2.

Fig. 108. (S 1064) X 2.5.

Fig. 109. (S 358 (B)) X 2.3.

Fig. 110. Note suprabasal inner primary veins.
(S 1046) X 2.2.

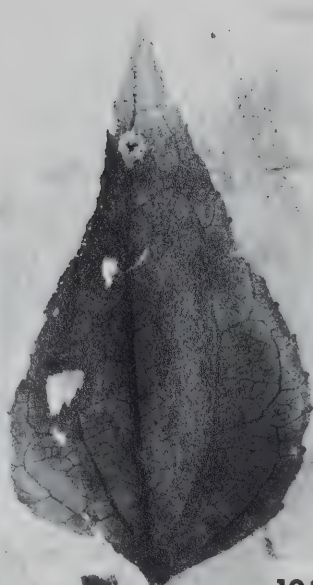
Fig. 111. (S 987 (A)) X 1.4.

(Collected from Genesee, Alberta).

PLATE 15



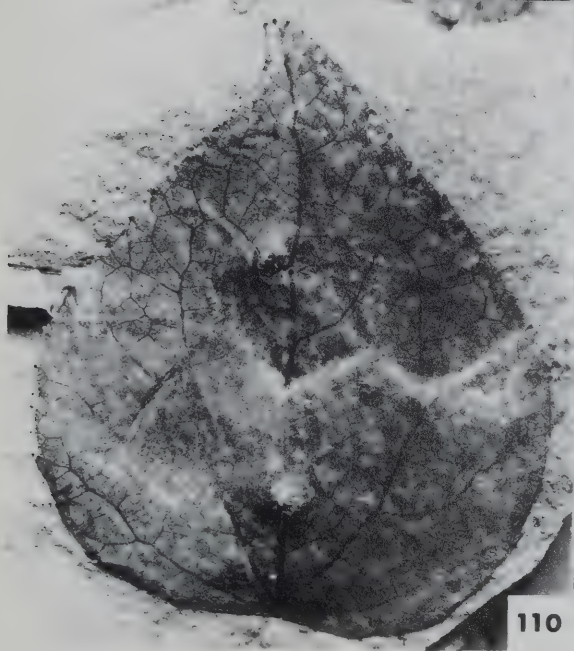
107



108



109



110



111

Plate 16.

Figs. 112-117. *Cercidiphyllum genesevianum* sp. nov..

Fig. 112. (S 1035) X 1.8.

Fig. 113. Enlarged portion of specimen in fig. 114 with details of venation. (S 1034) X 2.7.

Fig. 114. (S 1034) X 1.4.

Fig. 115. (S 2825) X 1.1.

Fig. 116. Enlarged portion of specimen in fig. 114 with mesophyll-configurations. X 22.

Fig. 117. Magnified portion of specimen in fig. 115 with mesophyll-configurations and minor venation. X 22.

(Collected from Genesee, Alberta).

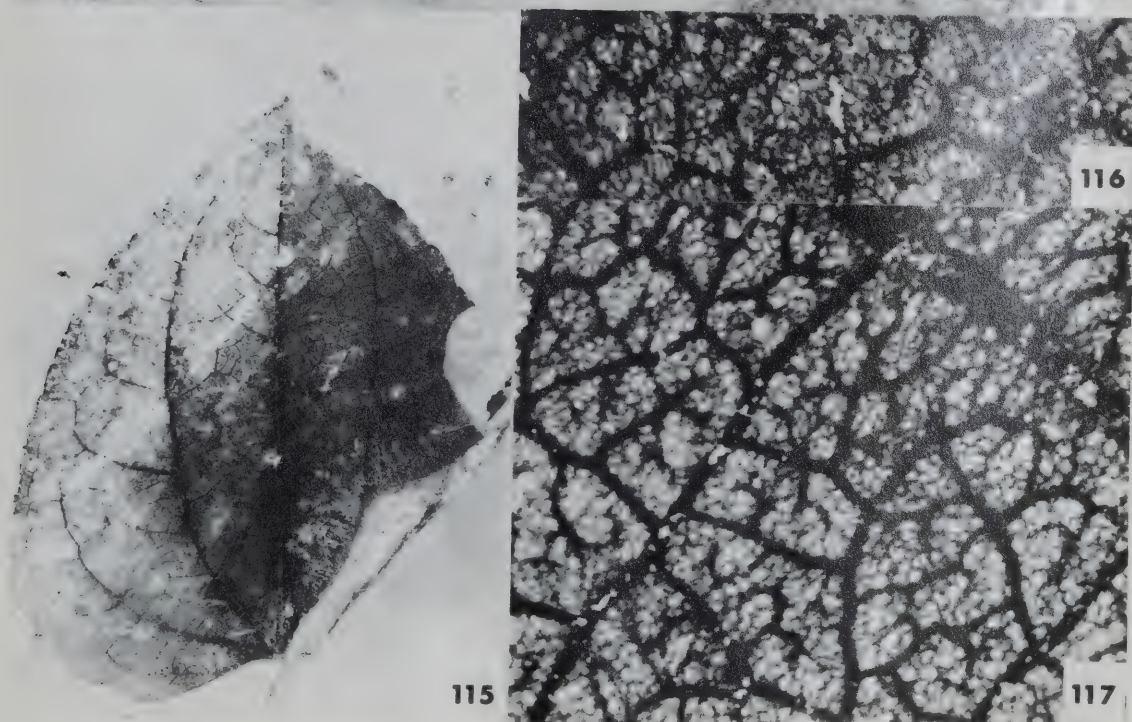
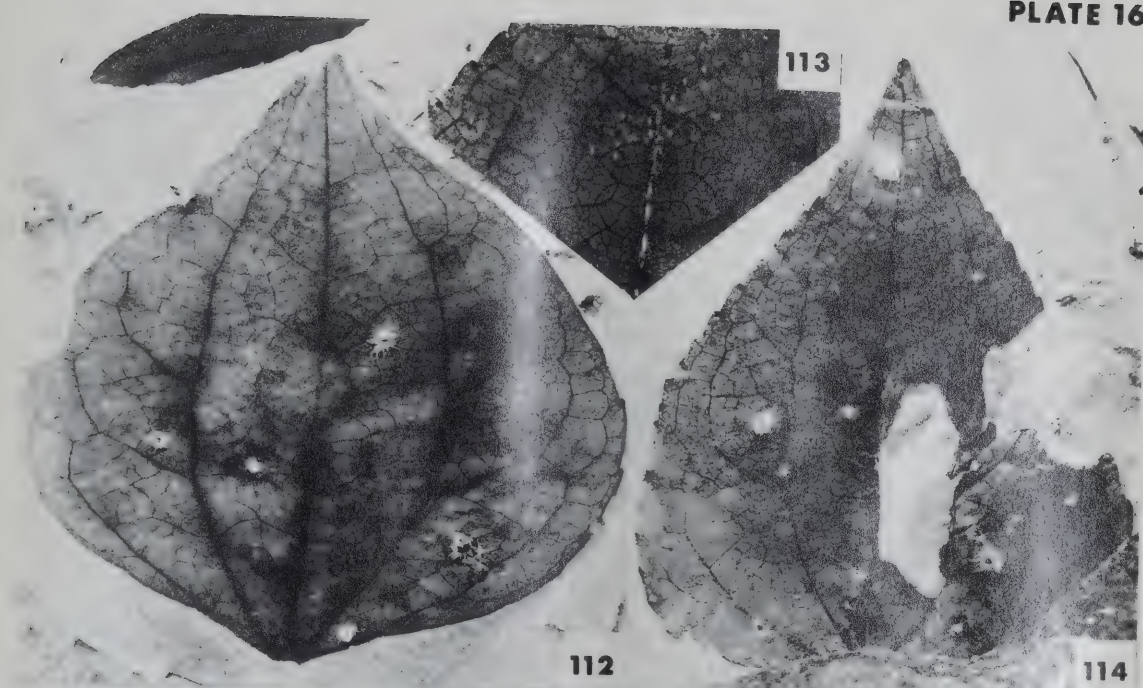


Plate 17.

Figs. 118-121. *Cercidiphyllum genesevianum* sp. nov..

Fig. 118. (S 1586 (A)) X 1.

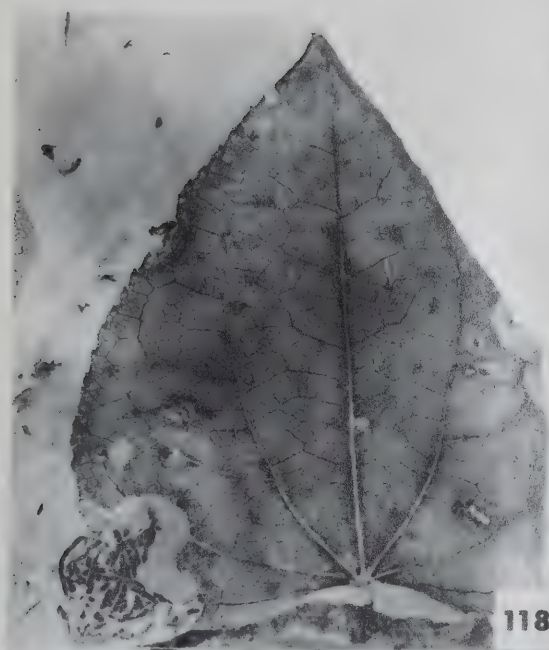
Fig. 119. (S 2850) X 1.

Fig. 120. (S 2852) X 1.

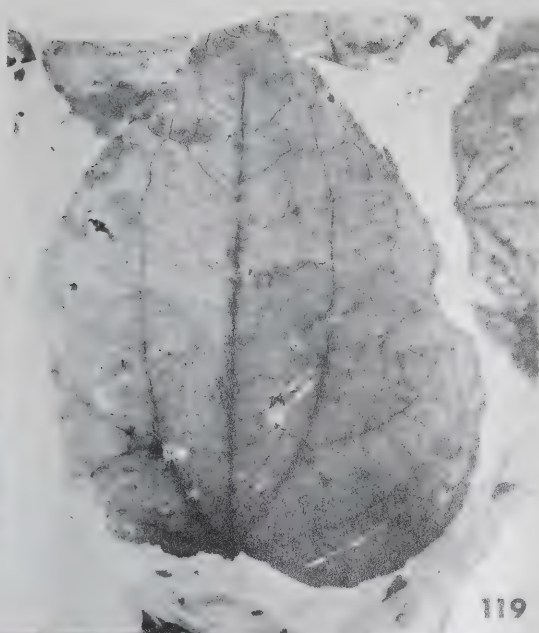
Fig. 121. Enlarged portion of specimen in fig. 120 with
mesophyll-configurations. X 25.

(Collected from Genesee, Alberta).

PLATE 17



118



119



120



121

87.

Plate 18.

Figs. 122-125. *Cercidiphyllum genesevianum* sp. nov..

Fig. 122. (S 229) X 2.4.

Fig. 123. Note acuminate leaf tip. (S 268) X 1.4.

Fig. 124. (S 300) X 1.8.

Fig. 125. Note serrate leaf margin. (S 3154) X 1.8.

(Collected from Genesee, Alberta).

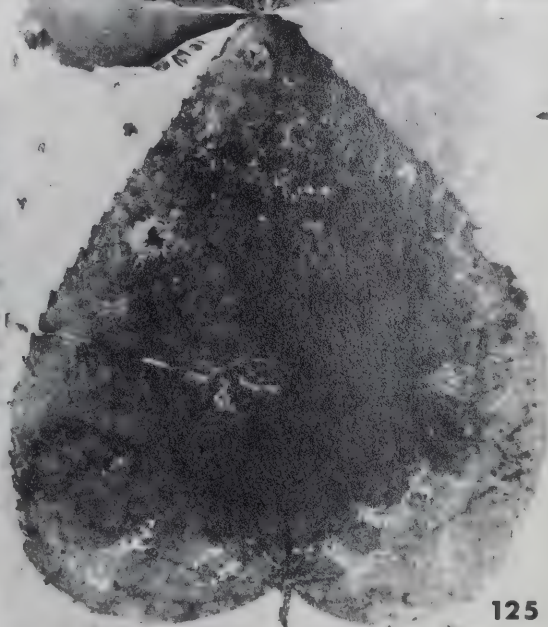
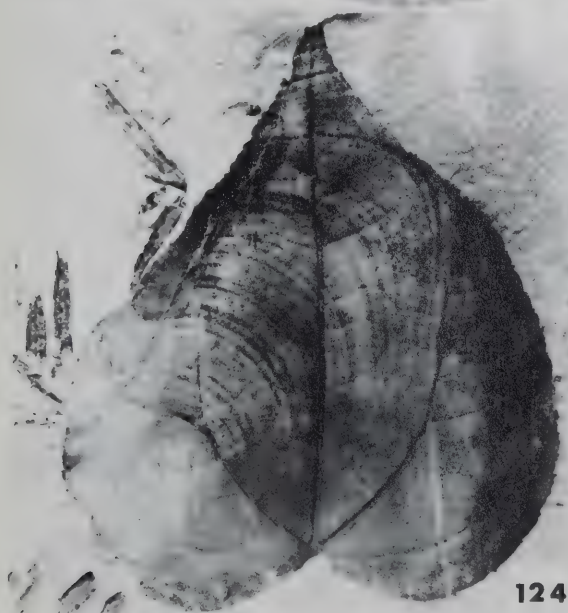


Plate 19.

Figs. 126-131. *Cercidiphyllum genesevianum* sp. nov..

Fig. 126. Note finely crenate leaf margin. (S 938 (B))
X 2.2.

Fig. 127. (S 1021) X 1.1.

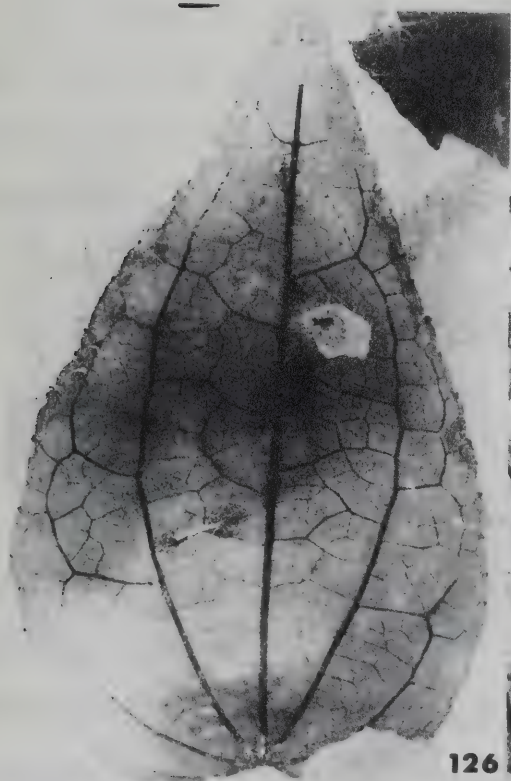
Fig. 128. Enlarged portion of specimen in fig. 118 (pl.
17) showing branched veinlets intruding vein
islets. (S 1586 (A)) X 11.

Fig. 129. Enlarged portion of a specimen, similar to
the one in fig. 127, with mesophyll-
configurations. (S 408) X 11.

Fig. 130. Variant with a cordate base. (S 1597) X 1.2.

Fig. 131. Variant with suprabasal inner primary veins
and conspicuous emergent glands on glandular-
entire leaf margin. (S 1327) X 1.6.

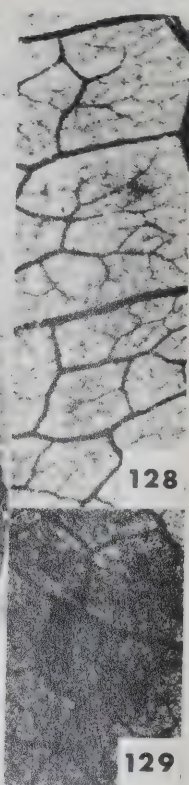
(Collected from Genesee, Alberta).



126

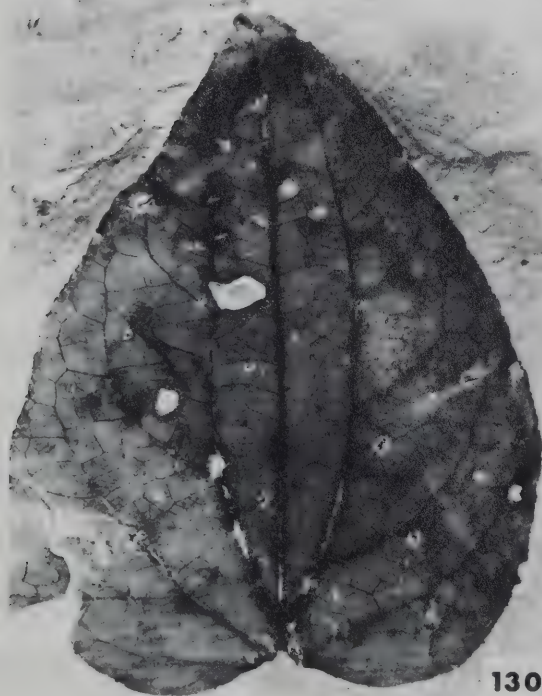


127

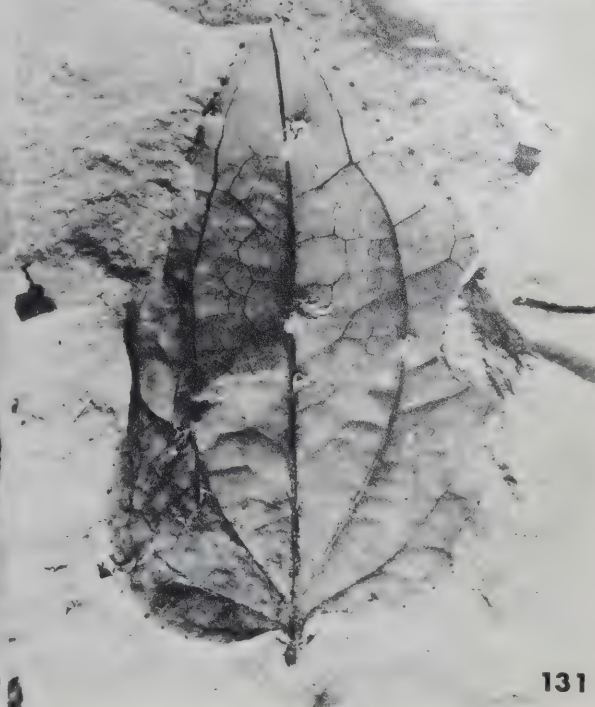


128

129



130



131

S 2852, S 1035, S 2825, S 1586 (A), S 1064, S 358 (B), S 1046 and S 987 (A) were collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta).

Cercidiphyllum flexuosum (Hollick) n. comb.

(Pl. 20, figs. 132 to 137; pl. 21, figs. 138 to 143; pl. 22, figs. 144 to 152), (Tables 16 to 18 append., graphs 1 to 5)

Populus flexuosa Hollick, 1936, p. 63, pl. 33, fig. 2.

Emended diagnosis: Texture chartaceous; petiolate; shape rhomboid, ovate or deltoid with a mean L/W ratio of 1.0 and a range of 0.7 to 1.7; leaf tip acute, rarely retuse, gland-tipped; margin rounded-serrate, crenate, dentate, rounded dentate with a mean of 3 teeth per cm and a range of 1 to 5 per cm, sinuses angular or rounded; gland placement on the margin, apical on the teeth nearer to the superadjacent sinus; glands generally inconspicuous, non-emergent but rarely conspicuous, emergent; base acute, obtuse, cuneate, truncate or incipient cordate; major venation palmate, strongly zig zag, midrib zig zag or straight flanked by 2 or 3 pairs of primaries, inner primaries strongest, basal in origin, zig zag, proximally straight up to the origin of the first outer secondary, ascending, divergent exceptionally parallel to midrib, diverging away from midrib above the widest portion of lamina, with a mean primary angle of 70° and a range of 45 to 100°; first strong secondaries arising

from the midrib, distal, conspicuous well above the widest portion of the lamina, opposite or alternate, straight or curved; superadjacent secondaries originating from midrib above the strong secondaries craspedo-camptodrome, zig zag forming irregular loops with each other as well as with the strong secondaries; mean strong secondary angle is 56° with a range of 40 to 65° ; inner primaries join first strong secondaries of the midrib forming angular loops; weak secondaries subjacent to the strong secondaries arising from the midrib, zig zag with a mean weak secondary angle of 59° with a range of 50 to 75° ; basal-most outer secondaries arising from inner primaries, alternate, percurrent, zig zag craspedo-camptodrome, with a mean outer secondary angle of 62° and a range of 50 to 75° ; outer secondaries of inner primaries forming angular, irregular series of loops with each other; middle primaries, when three pairs of primaries present, basal, zig zag, craspedo-camptodrome, joining the basal-most outer secondaries of the inner primaries forming irregular angular loops; outer primaries weakest, basal, zig zag, craspedo-camptodrome joining the basal-most outer secondaries of the middle primaries, when 3 pairs of primaries present or inner primaries when only 2 pairs of primaries present, forming irregular angular loops; outer branches of secondary loops forming a succession of loops with each other whose outer branches in turn form loops with each other resulting in angular irregular tertiary and quarternary loops; vein islets, polygonal, intruded by

simple or branched veinlets; veinlet is generally of equal thickness throughout its length; vein islet number with a mean of 7 and a range of 2 to 12; veinlet termination number with a mean of 9 and a range of 3 to 22; a single vein from a marginal loop enters a marginal tooth terminating at the base of a gland; mesophyll-configurations, small with a mean diameter of 40 μ .

Comment: The species exhibits a wide range in its foliar morphology. Out of a total of 150 specimens (Table 18) including recognizable fragments, 74 specimens were selected for analysis. Fifty-one specimens showed excellent preservation of minor venation (Table 17). In size, the smallest leaf (pl. 20, fig. 136) was 19 mm long and 12 mm wide with an approximate area of 152 sq mm and the largest leaf was 102 mm long and 110 mm wide with an approximate area of 7480 sq mm (specimen number S 919 (B) from Genesee, Alberta). Margin does not exhibit a high degree of variation. The glands, in general, are not conspicuous and appear to be degenerate (pl. 21, fig. 143, arrows). A few leaves show prominent, emergent glands (pl. 21, figs. 139 and 140, arrows). The glands have never been observed in the sinuses. A similar condition has been observed in most of the short shoot leaves of *Cercidiphyllum magnificum* (pl. 11, fig. 81). Variants of *Cercidiphyllum flexuosum* broadly fall in two categories, *viz.*, those with a rhomboid form (pl. 20, fig. 132) with a cuneate base, and those with a broad ovate form with a truncate or incipient cordate base (pl. 20, figs. 133

to 135; pl. 21, figs. 138, 141); but no absolute separation is possible because of their similar venation pattern. Table 16, reveals an interesting fact, *viz.*, no ovate form with a truncate base (base 180°) with an area less than 2000 sq mm was ever found in the collection, while the rhomboid forms with varying degrees of obtuseness of the leaf base (see Table 16) show a more uniform range starting from a very small leaf with an area of 152 sq mm. A possible interpretation is that the species possessed dimorphic foliage, one with a rhomboid form and another with an ovate form and that some of the small rhomboid forms (pl. 20, fig. 136) may represent immature stages of the ovate forms with a truncate or incipient cordate base. If this is true, then *C. flexuosum* represents a species whose leaves had a different growth pattern from the short shoot leaves of the modern *C. japonicum*. The ovate and broadly ovate forms with a truncate or incipient cordate base, resemble in over-all form and venation, the short shoot leaves of modern *Cercidiphyllum japonicum* (compare pl. 20, figs. 133 and 135, pl. 22, fig. 145 with pl. 11, fig. 72). The difference between the two species lies in the relative vein concentration per unit area. *C. flexuosum* has a denser concentration with a mean vein islet number of 7 as compared to 0.8 in *C. japonicum*. To put it in a different way, short shoot leaves of *C. japonicum* show larger vein islets compared to *C. flexuosum*. The veinlets intruding vein islets are of equal strength in *C. flexuosum*. This condition is seen in a few sucker shoot

leaves in *C. japonicum* (compare pl. 20, fig. 137, and pl. 12, fig. 83). A consistent feature common to both the species is the basal origin of the inner primaries. The mesophyll-configurations are small in *C. flexuosum*. They are not commonly observed in fossils from Genesee, Alberta, but are readily observed in specimens collected from Red Deer, Alberta (pl. 22, fig. 151 and specimen no. S 1975, paleobotanical collection, University of Alberta). In the short shoot leaves of *Cercidiphyllum japonicum* and leaves of *C. magnificum*, the mesophyll lacunae are small in size. Among other living plants leaves of species of *Populus* especially *P. tremula* Linn., a Chinese species similar to the North American *P. tremuloides*, *P. tremula* var. *daurica* Schneider and *P. sieboldii* Miq., a Japanese species, show a superficial similarity to the leaves of *C. flexuosum* in form and venation. But there are marked features of distinction between *Cercidiphyllum* and *Populus*. Species of *Populus* as a rule are pinnate in venation except for a few like *P. tremula* and *P. sieboldii* where a pinnate-palmate or palmate condition is seen. In such cases, the number^{of} pairs of primaries flanking the midrib is generally one and very rarely two. In addition the leaves possess a pair of conspicuous acropetiole glands, which are not observed in *Cercidiphyllum*. Moreover, the vein concentration per unit area is very high in species of *Populus*. This is specifically illustrated in *P. tremuloides* (Table 19) which shows a mean vein islet number of 10 and a mean veinlet termination number of 39.

These data are in no way comparable to that of *C. flexuosum* with a mean vein islet number of 7 and a mean veinlet termination number of 9. The data on *P. tremuloides* (Table 19) were obtained from leaves collected at random from a plant growing near the University of Alberta campus. It should also be recorded here that the acropetiolar glands are deciduous in ordinary leaves of *Populus tremuloides* but they were observed to be persistent in sprout leaves. Since the leaf variants of *C. flexuosum* resemble superficially the sprout leaves of *Populus tremuloides*, one should in a large enough sample expect at least a few specimens showing acropetiolar glands. But not a single fossil was found showing this structure.

A number of doubtful fossil species like *Populus genetrrix* Newberry (Hollick, 1936, p. 63, pl. 26, fig. 5), *Populus latior* Alex. Braun (Hollick, 1936, p. 64, pl. 26, figs. 1 and 2), *Populus glandulifera* Heer (Ward, 1887, p. 19, pl. 4, fig. 2), *Populus speciosa* Ward (Ward, 1887, p. 20, pl. 5, fig. 6 and 7), *Trochodendroides genetrrix* (Newberry) Brown (Brown, 1935, p. 577, pl. 68, fig. 4), *Trochodendroides arctica* (Heer) (Bell, 1949, p. 56, pl. 45, fig. 1; omit synonymy), and *Cercidiphyllum arcticum* (Heer) Brown (Brown, 1962, p. 70, pl. 38, fig. 10; omit synonymy) fall within the circumscription of *Cercidiphyllum flexuosum* (Hollick) with respect to certain features, judging from published descriptions and illustrations. It is doubtful whether the species listed above meet all the specific requirements of

Plate 20.

Figs. 132-137. *Cercidiphyllum flexuosum* (Hollick) n. comb..

Fig. 132. (S 1039 (A)) X 2.2.

Fig. 133. (S 2855) X 0.8.

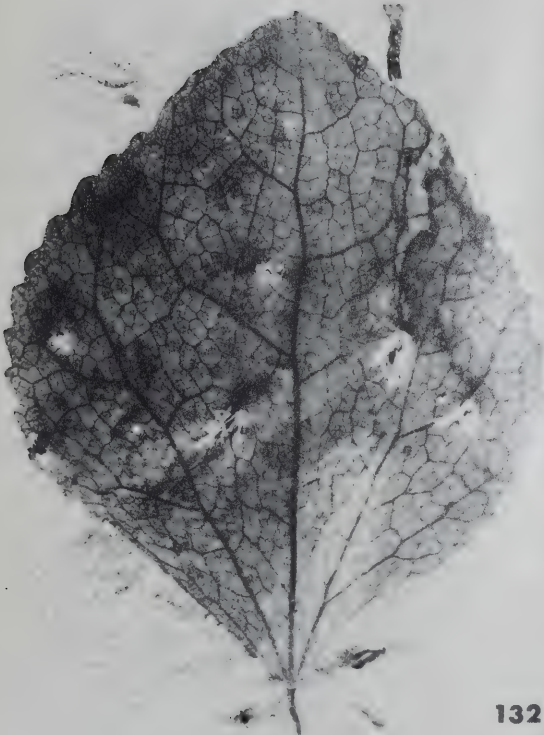
Fig. 134. (S 844 (B)) X 1.2.

Fig. 135. (S 2846) X 0.8.

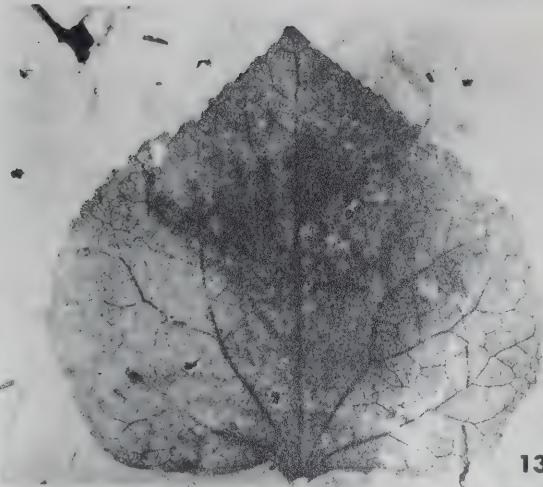
Fig. 136. (S 908) X 3.2.

Fig. 137. Enlarged portion of specimen in fig. 135
showing minor venation. (S 2846) X 10.

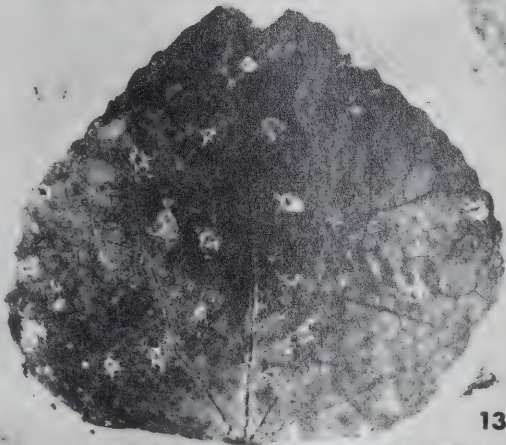
(Collected from Genesee, Alberta).



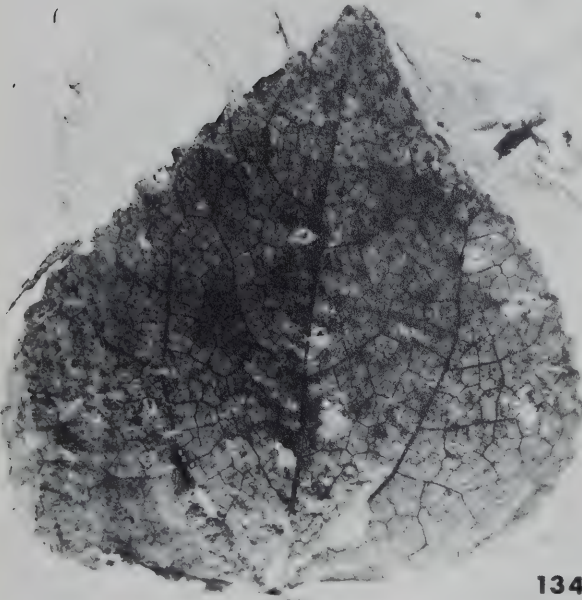
132



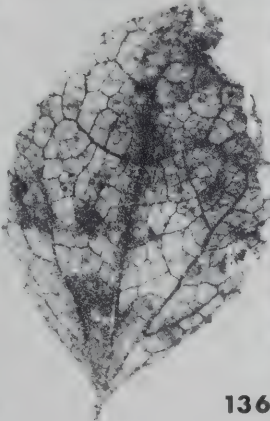
133



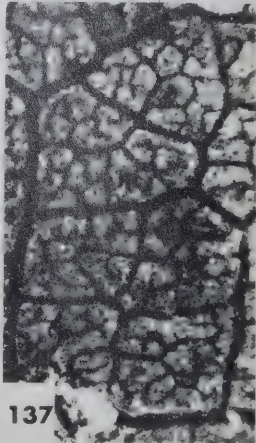
135



134



136



137

Plate 21.

Figs. 138-143. *Cercidiphyllum flexuosum* (Hollick) n. comb.

Fig. 138. Variant with incipient cordate base. (S 1584)
X 0.7.

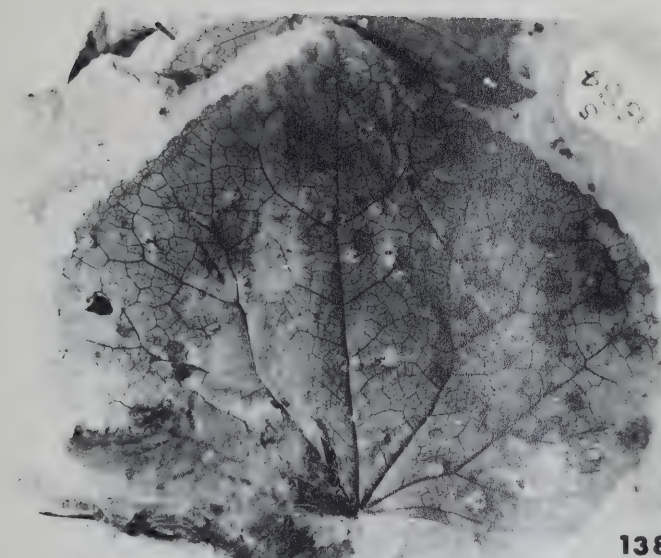
Fig. 139,140. Magnified portions of leaf margin with
emergent glands indicated by arrows.
gl=glands. (S 1059) X 9.

Fig. 141. (S 1015) X 1.1.

Fig. 142. Enlarged portion of specimen with vein
islets of variable size. (S 885) X 11.

Fig. 143. Enlarged portion of leaf margin with
degenerate glands indicated by arrows.
(S 310) X 9.

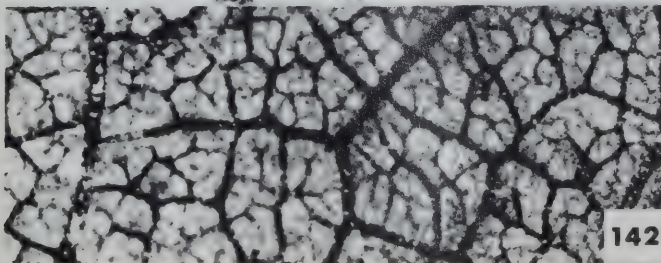
(Collected from Genesee, Alberta).



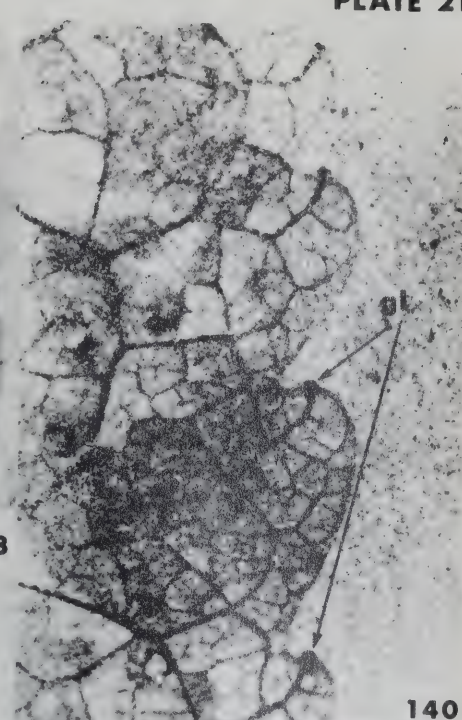
138



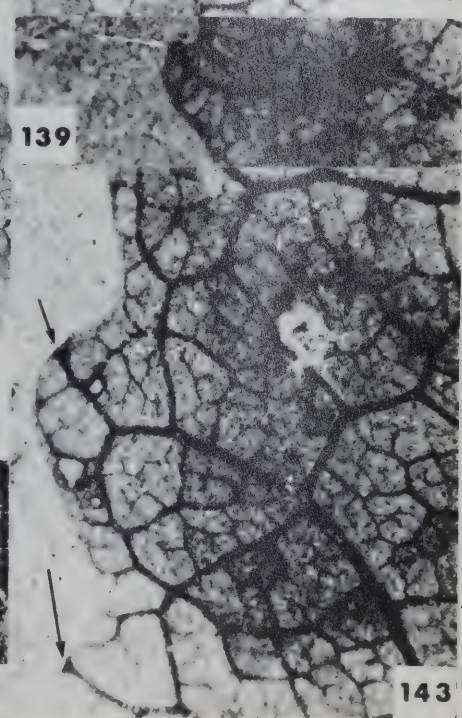
141



142



140



143

Plate 22.

Figs. 144-152. *Cercidiphyllum flexuosum* (Hollick) n. comb.

Fig. 144. (S 1745 (A)) X 0.8.

Fig. 145. (S 740) X 0.8.

Fig. 146. (S 758) X 0.8.

Fig. 147. (S 1780) X 0.8.

Fig. 148. (S 1974 (B)) X 0.8.

Fig. 149. (S 729) X 0.8.

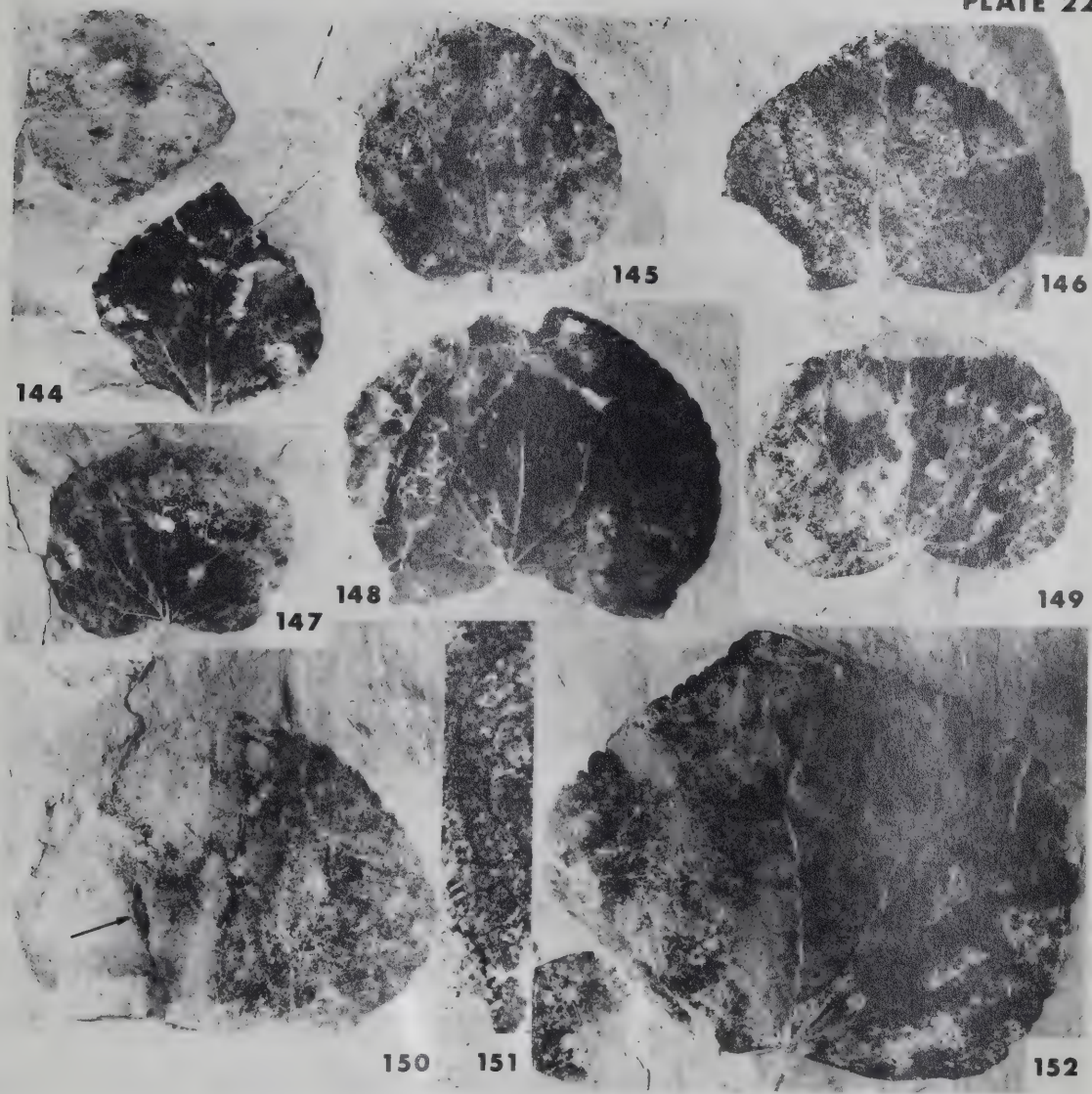
Fig. 150. Arrow indicates the area where mesophyll-
configurations are preserved. (S 683) X 0.8.

Fig. 151. Magnified area, indicated by arrow in fig.
150, with mesophyll-configurations. X 6.

Fig. 152. (S 1745 (A)) X 0.8.

(Collected from Red Deer, Alberta).

PLATE 22



Cercidiphyllum flexuosum (Hollick). Hence they are not synonymized.

(Figured specimens bearing numbers S 1039 (A), S 2855, S 844 (B), S 2846, S 908, S 1584, S 1584, S 1059, S 1015, S 885 and S 310 were collected from Genesee, Alberta; S 1745 (A), S 740, S 758, S 1780, S 1974 (B), S 729, S 683 and S 1745 were collected from Red Deer, Alberta, and deposited in the paleobotanical collection, University of Alberta).

Cercidiphyllum cuneatum (Newberry) n. comb.

(Pl. 23, figs. 153, 154, 156 to 162; pl. 24, figs. 163 to 166; pl. 25, figs. 168 to 172; pl. 26, figs. 173 to 181; pl. 27, figs. 182 to 188; pl. 28, figs. 189 to 194; pl. 29, figs. 195 to 200; pl. 30, figs. 201 to 204; pl. 31, figs. 205 to 209) (Tables 20 to 22 append., graphs 1 to 5).

Populus cuneata Newberry (Newberry, 1898, p. 41)

Emended diagnosis: Texture chartaceous, coriaceous; petiolate; shape ovate, very wide ovate with a mean L/W ratio of 1.2 and a range of 0.7 to 2.2; leaf tip acute or retuse, gland-tipped; margin entire, lobed, wavy, very wide serrate, rounded serrate, coarsely crenate, rounded irregular dentate; teeth small, large, frequency irregular with a mean of 1.5 per cm and a range of 0.5 to 3.0 per cm, sinuses angular, rounded, deeply rounded; gland placement on the margin, apical nearer to the superadjacent sinus, very

rarely in sinuses; glands, non-emergent, emergent; base rarely decurrent, cuneate, acute, obtuse truncate, incipient cordate; major venation palmate, zig zag; midrib part zig zag and part straight, zig zag, flanked by 2 or 3 pairs of primaries, inner primaries strongest smooth or zig zag, basal, very rarely suprabasal in origin, proximally straight up to the origin of the first outer secondary, ascending with a mean primary angle of 58° and a range of 40 to 90° , parallel to midrib or arcuate, curving up towards midrib distally or rarely divergent distally, to join the strong secondaries arising from the midrib; first strong secondaries arising from the midrib, distal, straight, conspicuous or inconspicuous, well above the widest portion of the lamina, opposite or alternate, with a mean strong secondary angle of 54° and range of 40 to 65° ; superadjacent secondaries arising from midrib above the strong secondaries, zig zag forming angular loops with each other as well as with the strong secondaries; weak secondaries subjacent to the strong secondaries arising from the midrib, zig zag with a mean weak secondary angle of 56° and a range of 45 to 75° ; basal-most outer secondaries arising from inner primaries, alternate, zig zag, rarely sinuous craspedo-camptodrome, with a mean outer secondary angle of 52° and a range of 40 to 65° ; outer secondaries of inner primaries forming angular loops with each other; middle primaries, when three pairs of primaries present, basal, zig zag, craspedo-camptodrome, joining the basal-most outer secondaries of the inner primaries forming angular

loops; outer primaries weakest, basal, zig zag, craspedo-camptodrome joining the basal-most outer secondaries of the middle primaries, when 3 pairs of primaries present, or inner primaries when only 2 pairs of primaries present, forming angular loops; outer branches of secondary loops forming angular loops with each other, whose outer branches in turn form a series of loops with each other, resulting in angular tertiary and quaternary loops; vein islets, polygonal, irregular, intruded by simple or branched veinlets; veinlet is of variable thickness; vein islet number with a mean of 1.9 and a range of 0.8 to 4; veinlet termination number with a mean of 5 and a range of 4 to 8; a single veinlet from a marginal loop enters a marginal tooth terminating at the base of a gland; mesophyll-configurations, large with a mean diameter of 70 μ .

Comment: *Cercidiphyllum cuneatum* (Newberry) constitutes a diverse assemblage of variants. From a total of 165 specimens including recognizable fragments, 92 specimens were analyzed. The smallest specimen was 22 mm long and 19 mm wide with an area of 278 sq mm; the largest specimen was 93 mm long and 102 mm wide with an area of 6324 sq mm. Some of the extreme variants are so unlike in over-all morphology that one could easily mistake them for different species in a small sample. Fortunately there are intermediate forms which link up the variants into a continuous spectrum. After many trials and combinations it was found impossible to segregate the group into discrete recognizable categories

and hence all the variants were lumped into a single species. The specific range in some cases, exceeds the limits of the genus as presently defined (Siebold and Zuccarini, 1846). The most striking and patent variability is seen in the leaf margin. The assemblage could be broadly divided into two categories, one, where the specimens have an entire margin (pl. 23, figs. 153, 154, 157, 158, 162; pl. 25, fig. 169; pl. 26, figs. 173, 176, 177, 179), and the other with a non-entire margin (pl. 24, figs. 163 to 165; pl. 25, figs. 167, 170; pl. 26, fig. 178; pl. 27, figs. 182, 183, 185, 186, 188; pl. 28, figs. 189 to 192; pl. 29, figs. 195, 196, 198, 200; pl. 30, figs. 201 to 204; pl. 31, figs. 205 to 209). Figure 162 (pl. 23) and figure 178 (pl. 26) show identical venation, leaf shape and an entire margin. But when studied critically figure 178 (pl. 26), exhibits two rudimentary glands (indicated by arrows in the figure; see also pl. 26, fig. 181 where the glands are shown magnified), which are vascularized. To illustrate again, a comparison of figure 157 (pl. 23) with figure 163 (pl. 24) shows that both specimens are identical in venation, but the leaf in figure 163 (pl. 24) exhibits widely spaced serrations (indicated by arrows in the figure) with glands at the tips of the teeth. Leaf variants like those shown in figure 178 (pl. 26) and figure 163 (pl. 24) link up the entire-margined specimens with more elaborately toothed variants. In the non-entire margined leaves the serrations may appear as projections from the margin at about the widest portion of the leaf (pl. 24,

fig. 165, arrow; pl. 25, fig. 167, arrow; pl. 27, fig. 185, arrow; fig. 188, arrow), or if there is more than one serration, they may be widely spaced (pl. 24, fig. 163; pl. 25, fig. 170; pl. 27, figs. 183, 186; pl. 28, fig. 192) or closely spaced (pl. 24, fig. 164; pl. 28, fig. 189, 191; pl. 29, figs. 195, 196, 198, 200; pl. 30, figs. 201 to 203). In fact, figure 189 (pl. 28) illustrates an intermediate stage between the widely-serrated variants and closely-serrated variants. Serrations are always rounded and gland-tipped. The glands are not observed in some of the dark, widely-serrated variants, but they are readily observed in closely-serrated leaves (pl. 29, fig. 199). The glands are normally apical in position on the teeth and they may be emergent or non-emergent. The non-emergent gland illustrated in figure 199 (pl. 29) is strikingly similar in appearance to some of the glands found in dry leaves of *Cercidiphyllum japonicum* (pl. 11, fig. 74; arrow without label points to the gland). The marginal configuration may sometimes be so irregular that proper scientific description is impossible (pl. 31, figs. 205, 206, 208). Sinuses are angular (pl. 29, fig. 196) or rounded (pl. 29, figs. 195, 200). The large rounded-serrate margin and the irregular dentition bears considerable resemblance to the long shoot leaves of *Cercidiphyllum magnificum* (compare pl. 29, fig. 195 and pl. 30, fig. 201 with pl. 10, fig. 69). In well-preserved specimens a gland is always present at the apex of the leaf (arrows in pl. 23, figs. 159, 160, indicate glands; compare

with pl. 23, fig. 161 showing an apical gland in *Cercidiphyllum magnificum* indicated by the arrow). The leaf base is decurrent in a few specimens. This condition is common to both entire and non-entire margined forms (pl. 24, fig. 165; pl. 25, fig. 169; pl. 26, figs. 178, 179; pl. 27, figs. 185 and 186; pl. 28, fig. 190; pl. 29, fig. 196; pl. 30, fig. 202). With respect to major venation, the inner primaries are mostly basal in origin but one specimen was found showing suprabasal origin (pl. 31, fig. 205). Minor venation is typically cercidiphylloid with irregular vein islets intruded by ramified veinlets (pl. 26, fig. 180). In minor venation no difference is observed between the entire-margined variants and non-entire margined variants (compare pl. 26, fig. 174 with pl. 28, fig. 194). Mesophyll-configurations are large (pl. 23, fig. 156; pl. 24, fig. 166; pl. 25, figs. 171, 172; pl. 26, fig. 174; pl. 27, figs. 184, 187; pl. 28, figs. 193, 194). Among living plants, some of the entire-margined variants of *Cercidiphyllum cuneatum* (Newberry) resemble some menispermaceous members, especially *Cocculus* D.C., (Forman, 1960) in leaf form and palmate venation. A study of twenty cleared leaves and numerous herbarium sheets of *Cocculus trilobus* (Thunb.) D.C., *C. thunbergii* D.C., *C. orbiculata* Kuntze., revealed a few significant and consistent features, like an entire margin, an apical mucro, a strong marginal vein, small, regular vein islets with simple or sparsely branched veinlets intruding the vein islets. The mean vein islet number in *Cocculus trilobus* D.C., to which

the entire-margined leaves of *Cercidiphyllum cuneatum* bear the strongest resemblance, was found to be 3.6 with a range 2.2 to 4 (Table 23). The mean veinlet termination number was found to be 4.2. It must be admitted that the mean veinlet termination number of 4.2 is very close to the mean veinlet termination number of 5, shown by *C. cuneatum*. But it is doubtful whether any significance could be attached to this feature because, the other two species, *C. genesevianum* and *C. flexuosum* (Hollick) also exhibit low veinlet termination numbers, i.e., 6 and 9 respectively. Moreover, the venation in species of *Cocculus* D.C. in general was observed to be sinuous and rarely straight or zig zag. The question now is, whether *Cercidiphyllum cuneatum* (Newberry) exhibits a cocculoid foliar morphology, or a cercidiphylloid foliar morphology especially in view of the entire-margined variants. It should be acknowledged at this point, that the living *Cercidiphyllum* has never been observed to show a completely entire margin in a strict sense, i.e., without a trace of glands, although a glandular-entire margin is regularly observed. The important point here is that, while a range of variation in marginal configuration from glandular-entire to crenate is regularly observed in *Cercidiphyllum*, such a variation is never seen in *Cocculus*. As already noted above, *Cocculus* shows a consistent entire margin, and there is no evidence as yet, that the genus ever possessed a margin other than entire, i.e., toothed margin with glands, or glandular-entire margin. These facts as applied to *Cercidiphyllum*

cuneatum, which shows a spectrum of variation of entire and non-entire margin leads to two alternative interpretations. Either, that the species is cercidiphylloid in its foliar affinity because of the presence of variants having a non-entire margin with prominent glands, or cocculoid because of the presence of variants having an entire margin. If the latter interpretation is accepted, then one must assume that *Cocculus* had a toothed margin with glands in its ancestry similar to *Cercidiphyllum cuneatum* and that the entire margin was derived during evolution, with a complete loss of marginal configuration as observed in the modern genus. A critical study of the species of modern *Cocculus* D.C. does not warrant such an assumption. The hypothesis though attractive fails on other grounds too. As already stated, species of *Cocculus* in general and *C. trilobus* in particular, consistently show an apical mucro, a marginal vein, and very small spongy mesophyll lacunae having a mean diameter of 20 μ . None of these features was observed in *Cercidiphyllum cuneatum*. On the other hand a number of features in common with *Cercidiphyllum* have been recorded above, with the exception of an entire margin. Even the presence of an entire margin in *C. cuneatum* does not seriously hamper its inclusion in the generic circumscription of *Cercidiphyllum* because a degenerate (in a purely morphological sense) marginal configuration, except for the presence of glands, is often seen in *Cercidiphyllum*. Thus, foliar features of *C. cuneatum* when weighed against *Cocculus* and

Cercidiphyllum, seem to favour a cercidiphylloid rather than a cocculoid affinity. In any event, the decision to remove *C. cuneatum* from *Cercidiphyllum* and place it in a new form genus closely allied to *Cercidiphyllum* would be purely subjective. It depends upon the relative significance attached to an entire margin showing no trace of glands. Granted that such a procedure is valid, the only result it achieves is the addition of yet another name to the already proliferate lists of names which abound in the literature. A more satisfactory alternative seems to be to expand the generic range of *Cercidiphyllum*, in view of the consistent presence of a degenerate glandular-entire margin, to include the entire-margined variants of *C. cuneatum*. This procedure was adopted in the emended diagnosis of this species.

Among the numerous fossil species which bear resemblance in some of their features to some of the variants of *C. cuneatum* are: *Populus arctica* Heer (Hollick, 1936, p. 60, pl. 22, fig. 5 (a); pl. 23, figs. 1, 2; pl. 24, fig. 1; pl. 117, figs. 6, 8), *Populus zaddachi* Heer? (Hollick, 1936, p. 69, pl. 24, figs. 4, 5; pl. 116, fig. 5), *Grewiopsis mclearnii* Berry (Berry, 1935, p. 50, pl. 12, fig. 3; pl. 14 A), *Trochodendroides arctica* (Heer) Berry (Berry, 1926, p. 109, pl. 13, figs. 1 to 3; Seward and Conway, 1935, p. 15, pl. 3, fig. 22; pl. 5, fig. 39; Bell, 1949, p. 56, pl. 20, fig. 3; pl. 45, fig. 2; pl. 46, figs. 2, 3), *Trochodendroides rhomboideus* (Lesquereux) Berry (Berry, 1922, p. 166, pl. 36, fig. 5), *Trochodendroides cuneata* (Newberry) Berry (Berry,

1930, p. 20, pl. 5, figs. 2 and 3; 1935, p. 34, pl. 6, figs. 2-6), *Cercidiphyllum arcticum* (Heer) Brown (Brown, 1939, p. 492, pl. 53, figs. 4, 6 (middle and left); Schloemer-Jäger, 1958, p. 68, pl. 10, fig. 7; Brown, 1962, p. 70, pl. 37, figs. 15, 17, 20; pl. 52, fig. 9; Koch, 1963, p. 47, pl. 17, figs. 2 and 3), Hamamelidaceae? Genus? (Chandler, 1961, p. 70, pl. 6, fig. 5). Original types of some of these species were examined. Some show some of the characteristics described under *C. cuneatum* (Newberry) but not all. Hence they are not synonymized.

(Figured specimens bearing numbers S 874 (L), S 245, S 1041, S 2717, S 295, S 275, S 2725, S 1598, S 1586 (A) and S 1587 (A), S 1586 (A), S 1043, S 358 (A), S 914 (A), S 1031, S 283, S 374, S 311, S 250, S 957 (A), S 1069 (B), S 2827, S 897, S 2845, S 982, S 988, S 3215 (A), S 301, S 399, S 1341, S 2861 (B), S 328, S 2868, S 2718 (A), S 1051 (B), S 271, S 336, S 884, S 863, S 2716 (A) and S 1078 (A) were collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta).

Cercidiphyllum sp. Fruits

(Pl. 32, figs. 210 to 214)

Description: Fruits rounded, elliptic, flat, slightly convex in the middle, tapering proximally and distally. Apex drawn into an extended point, very short stalked almost sessile. Fruits opposite, or alternate on an elongated,

Plate 23.

Fig. 153. *Cercidiphyllum cuneatum* (Newberry) n. comb..
 (S 874 (L)) X 2.2.

Fig. 154. *Cercidiphyllum cuneatum* (Newberry) n. comb..
 (S 245) X 0.9.

Figs. 156-160. *Cercidiphyllum cuneatum* (Newberry) n. comb..

Fig. 156. Enlarged portion of specimen in fig. 157 with
 mesophyll-configurations. (S 1041) X 9.

Fig. 157. (S 1041) X 1.8.

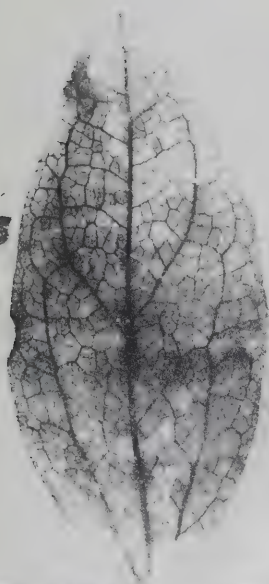
Fig. 158. (S 2717) X 0.9.

Figs. 159,160. Depressions at leaf apices, indicated by
 arrows, originally filled with carbon.
 Depressions presumably glandular. \ (S 295)
 X 11 and (S 275) X 11 respectively. Compare
 the depressions with the gland indicated by
 arrow in fig. 161.

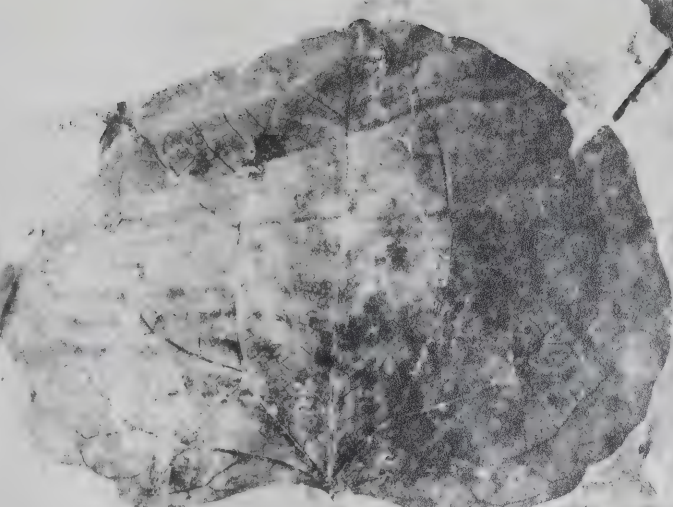
Fig. 161. Apical portion of cleared long shoot leaf of
 extant *Cercidiphyllum magnificum* (Nakai)
 Nakai with apical gland, indicated by arrow,
 for comparison with figs. 159 and 160 above.
 X 11.

Fig. 162. (S 2725) X 1.8.

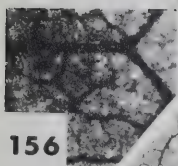
(Collected from Genesee, Alberta).



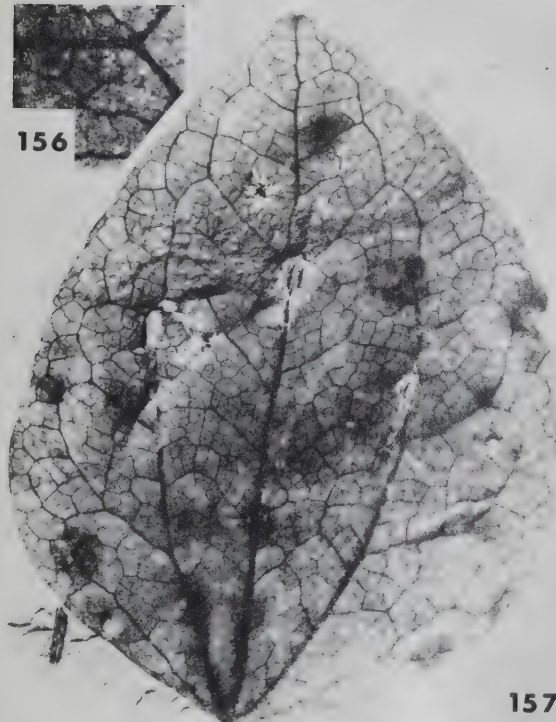
153



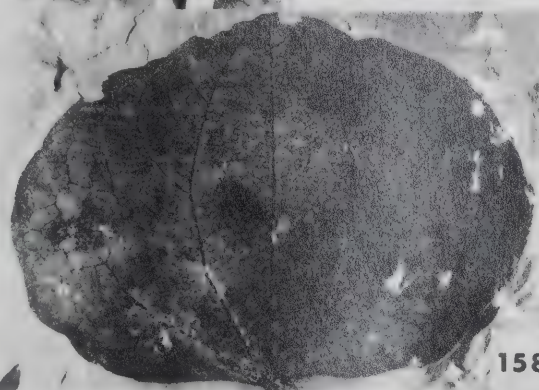
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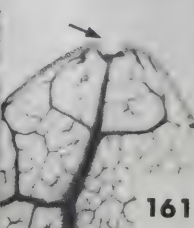
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159



160



161

Plate 24.

Figs. 163-166. *Cercidiphyllum cuneatum* (Newberry) n. comb..

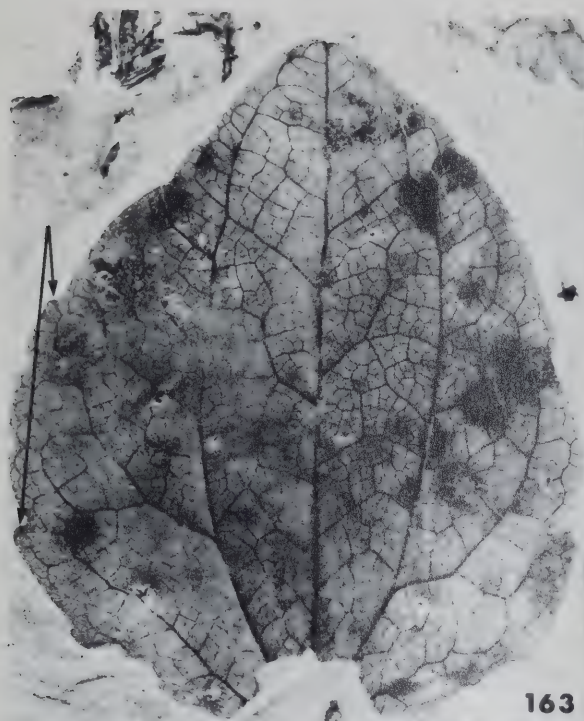
Fig. 163. Specimen with widely separated rounded serrations and inconspicuous glands indicated by arrows. (S 1598) X 1.8.

Fig. 164. Specimen with partly entire and partly rounded serrate (left) margin. (S 295) X 1.

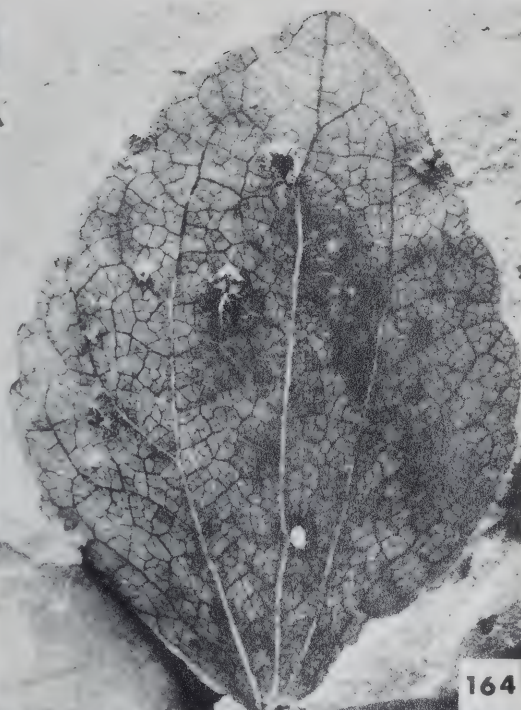
Fig. 165. Specimen with rounded serrations on the margin. Arrow points to carbonized mass at the tip of serration, presumably glandular. (S 1586 (A) and S 1587 (A)) X 0.9.

Fig. 166. Enlarged portion of specimen in fig. 165 with mesophyll-configurations. (S 1586 (A)) x 22.

(Collected from Genesee, Alberta).



163



164



165



166

110.

Plate 25.

Figs. 167-172. *Cercidiphyllum cuneatum* (Newberry) n. comb..

Fig. 167. Arrow indicates projection from leaf margin.
 (S 1043) X 2.5.

Fig. 168. Enlarged portion of specimen in fig. 169
 showing minor venation. (S 358 (A)) X 11.

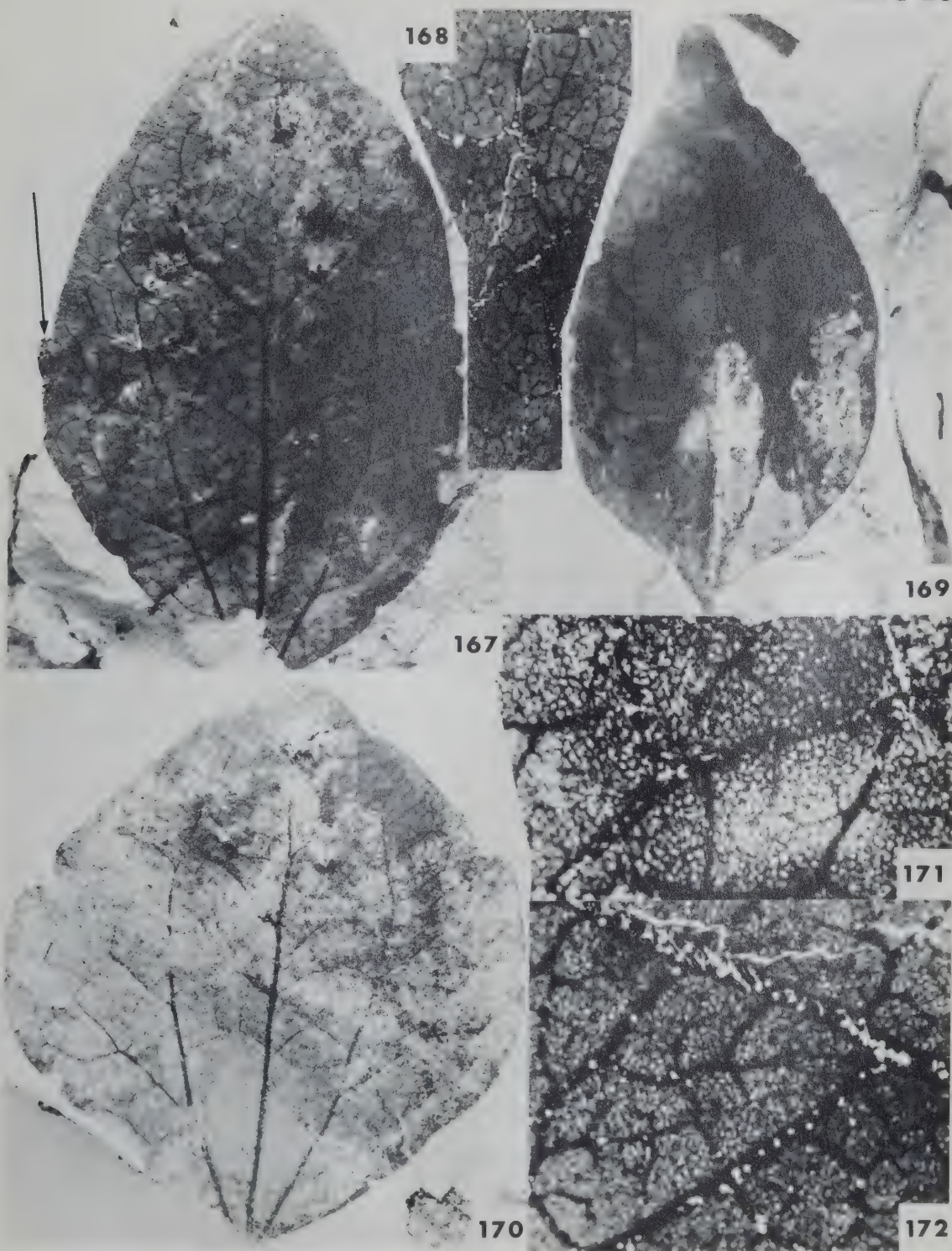
Fig. 169. (S 358 (A)) X 1.6.

Fig. 170. Specimen with widely separated rounded
 serrations on leaf margin. (S 914 (A)) X 2.2.

Fig. 171. Enlarged portion of specimen in fig. 167
 with mesophyll-configurations. X 22.

Fig. 172. Enlarged portion of specimen in fig. 169
 with mesophyll-configurations. X 22.

(Collected from Genesee, Alberta).



111.

Plate 26.

Figs. 173-181. *Cercidiphyllum cuneatum* (Newberry) n. comb..

Fig. 173. (S 1031) X 0.8.

Fig. 174. Enlarged portion of specimen in fig. 173 with mesophyll-configurations. X 8.

Fig. 175. Gland at the apex of leaf (fig. 173) indicated by arrow. X 10.

Fig. 176. (S 283) X 0.8.

Fig. 177. (S 374) X 0.8.

Fig. 178. Specimen with entire margin on the left and two rudimentary vascularized projections on the right indicated by arrows. (S 311) X 1.6.

Fig. 179. (S 250) X 0.8.

Fig. 180. Enlarged portion of specimen in fig. 179 with minor venation. X 8.

Fig. 181. Enlarged portion of leaf margin of specimen in fig. 178 with glands indicated by arrows. gl=glands. X 10.

(Collected from Genesee, Alberta).

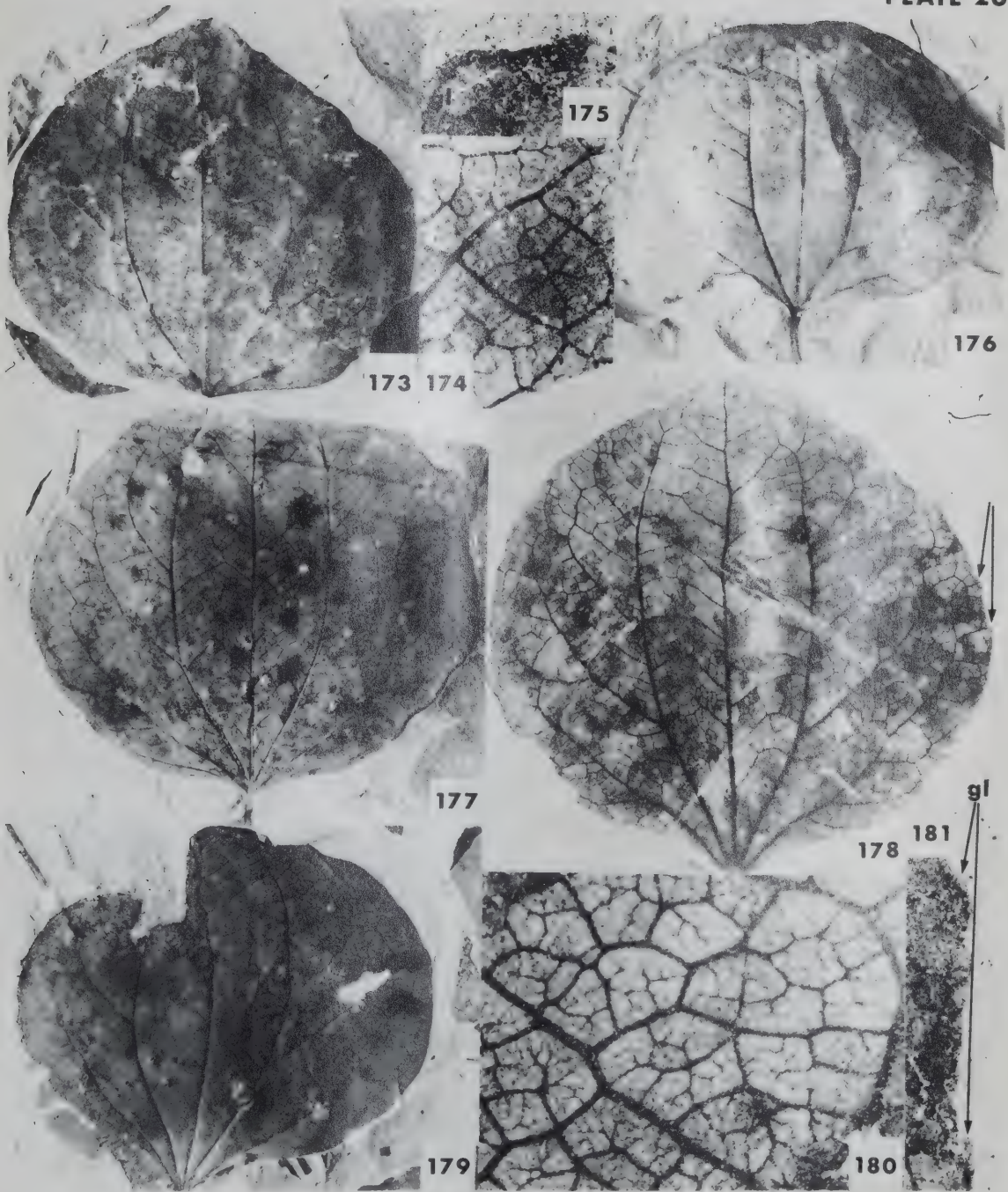


Plate 27.

Figs. 182-188. *Cercidiphyllum cuneatum* (Newberry) n. comb..

Fig. 182. (S 957 (A)) X 0.9.

Fig. 183. (S 1069 (B)) X 0.9.

Fig. 184. Enlarged portion of specimen in fig. 185
with mesophyll-configurations. (S 2827) X 11.

Fig. 185. (S 2827) X 0.7.

Fig. 186. Note decurrent base, widely separated rounded
serrations on the margin and retuse leaf tip.
(S 897) X 0.9.

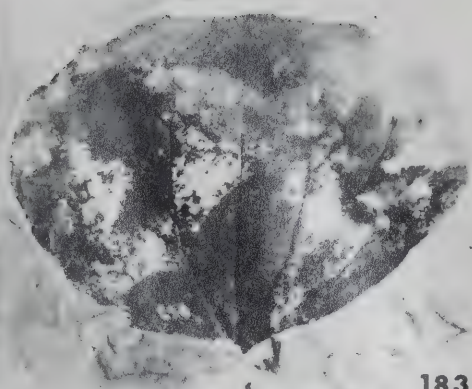
Fig. 187. Enlarged portion of specimen in fig. 188 with
mesophyll-configurations. (S 2845) X 22.

Fig. 188. Note widely spearated rounded serrations on
the margin. An emergent gland is indicated by
the arrow (right). (S 2845) X 1.1.

(Collected from Genesee, Alberta).



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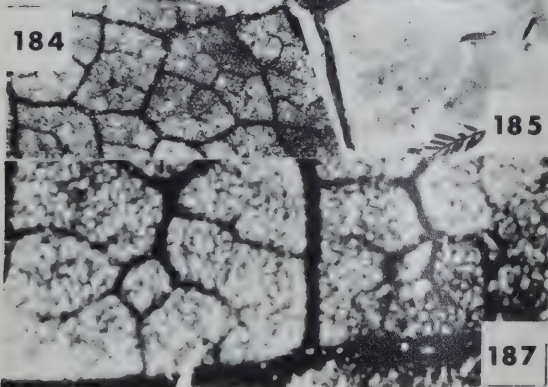
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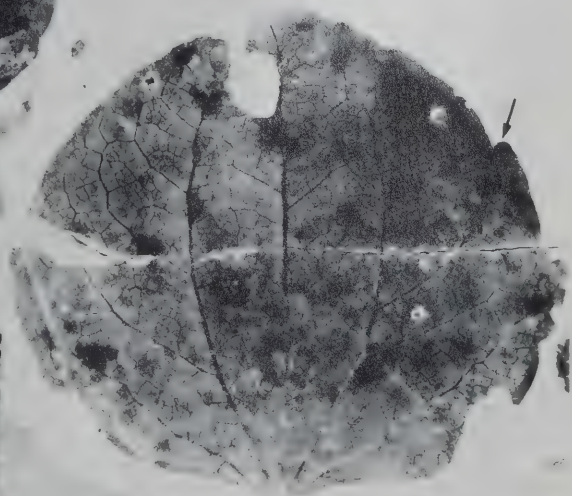
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184



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188

187

Plate 28.

Figs. 189-194. *Cercidiphyllum cuneatum* (Newberry) n. comb..

Fig. 189. (S 982) X 0.9.

Fig. 190. (S 988) X 1.4.

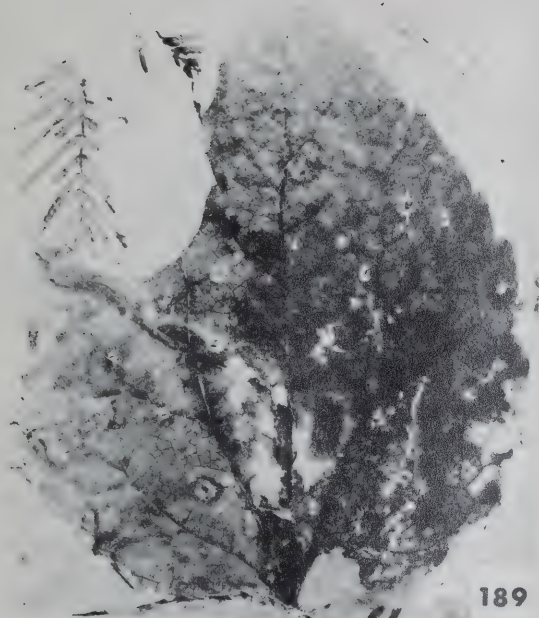
Fig. 191. (S 3215 (A)) X 0.9.

Fig. 192. (S 301) X 1.5.

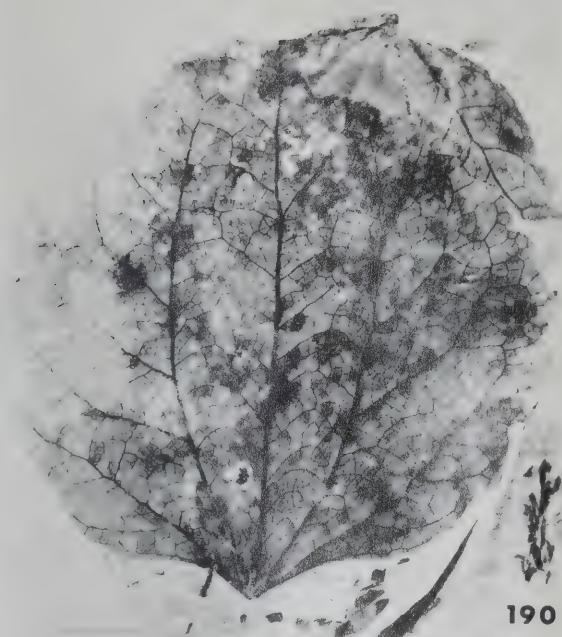
Fig. 193. Enlarged portion of specimen in fig. 189
with mesophyll-configurations. (S 982) X 9.

Fig. 194. Enlarged portion of specimen in fig. 190
with minor venation and mesophyll-configura-
tions. (S 988) X 9.

(Collected from Genesee, Alberta).



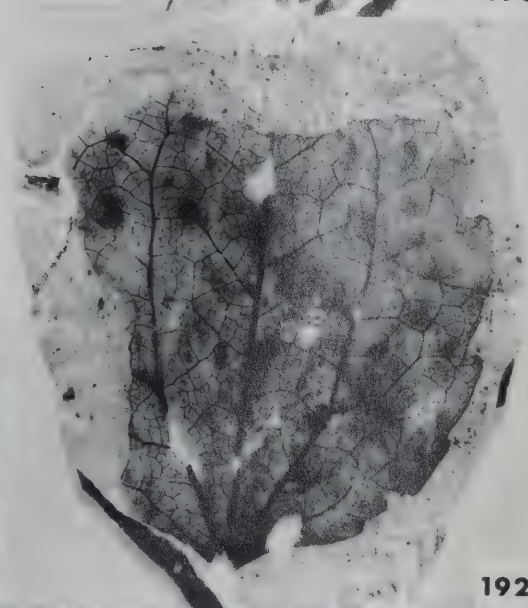
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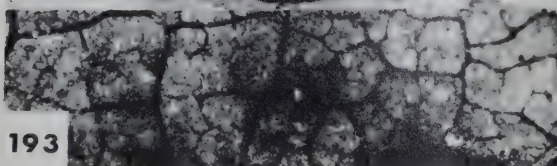
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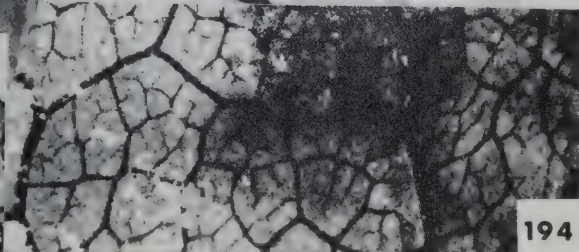
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192



193



194

114.

Plate 29.

Figs. 195-200. *Cercidiphyllum cuneatum* (Newberry) n. comb.

Fig. 195. (S 399) X 2.1.

Fig. 196. (S 1341) X 1.2.

Fig. 197. Enlarged portion of specimen in fig. 196 with
mesophyll-configurations. X 22.

Fig. 198. (S 2861 (B)) X 0.9.

Fig. 199. Enlarged portion of leaf margin of specimen
in fig. 198. Arrow indicates a non-emergent
gland. gl=gland. X 11.

Fig. 200. (S 328) X 1.4.

(Collected from Genesee, Alberta).



115.

Plate 30.

Figs. 201-204. *Cercidiphyllum cuneatum* (Newberry) n. comb..

Fig. 201. (S 2868) X 1.5.

Fig. 202. (S 2718 (A)) X 0.9.

Fig. 203. (S 1051 (B)) X 0.9.

Fig. 204. (S 271) X 0.9.

(Collected from Genesee, Alberta).

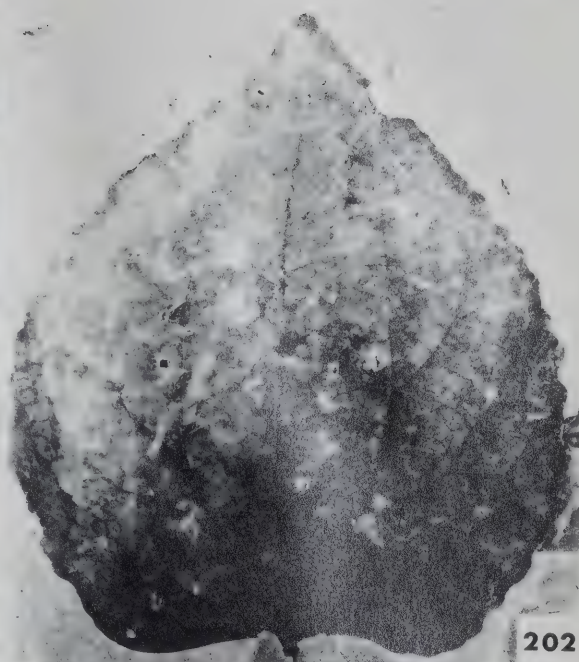


Plate 31.

Figs. 205-209. *Cercidiphyllum cuneatum* (Newberry) n. comb..

Fig. 205. Note suprabasal inner primary veins and
irregular dentition. (S 336) X 0.9.

Fig. 206. (S 884) X 0.9.

Fig. 207. (S 1078 (A)) X 1.5.

Fig. 208. (S 863) X 0.9.

Fig. 209. (S 2716 (A) (L)) X 1.2.

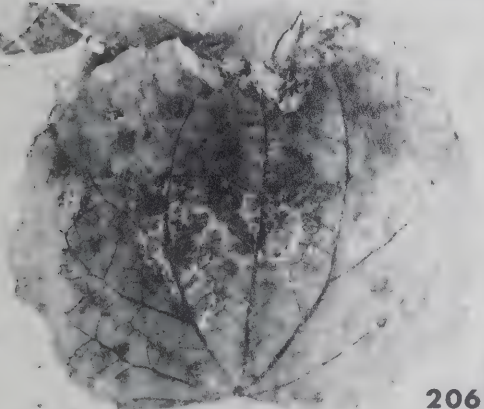
(Collected from Genesee, Alberta).



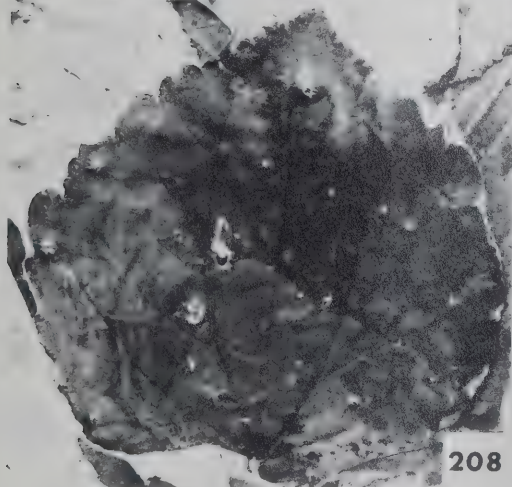
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207



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208



209

thick axis. Fruits longitudinally striated externally, with 15 to 18 striations, evenly spaced and converging at either end. Transversely striated internally, striations light and inconspicuous. Average size of fruit, length 20 mm and width 7 mm.

Comment: The reproductive structures are rare. Those that have been seen are very similar in morphology. Only 7 specimens were found in the collection. The fruits are dark, carbonized and the internal cavities are preserved as casts. Sometimes the fruits occur in pairs (pl. 32, fig. 213). The slitlike dehiscence suture is always visible (pl. 32, figs. 211, 214). No organic connection was observed between any type of foliage and the fruits. Ten fruits were measured. They show a range of 15 to 25 mm in length and 6 to 10 mm in width. No seeds were discovered.

These fruits are of widespread occurrence in lower Tertiary floras of western U.S., Canada, Alaska, Greenland, and other circum-polar regions. The fruits are practically identical with *Leguminosites? arachioides* Lesquereux (Berry, 1916, p. 249, pl. 48, fig. 9) and *Cercidiphyllum arcticum* (Heer) Brown (Brown, 1939, pl. 54, figs. 8, 9, 14; Koch, 1963, p. 47, pl. 20, fig. 1).

Brown (1939, 1962) considers the fruits cercidiphylloid. Chandler (1961), however, does not favour this affinity but refers the fruits to a genus of Hamamelidaceae. So far, the Genesee material has failed to throw any further light on the nature of the fruits or their systematic affinities.

118.

Plate 32.

Figs. 210-214. *Cercidiphyllum* sp.. Fruits.

Fig. 210. (S 990 (B)) X 1.3.

Fig. 211. Fruit (right) with suture of dehiscence.

(S 943) X 2.7.

Fig. 212. (S 2842 (B)) X 1.6.

Fig. 213. Fruits with longitudinal striations.

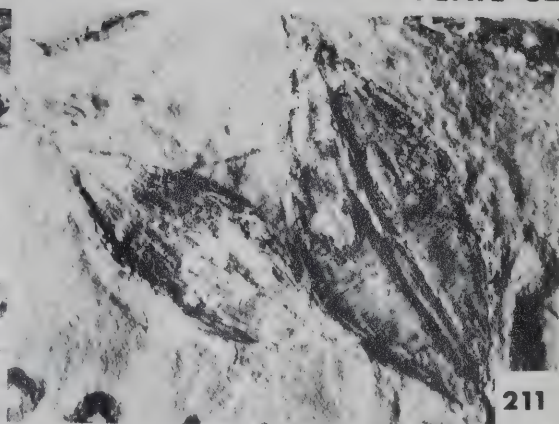
(S 1009) X 3.6.

Fig. 214. (S 1547) X 0.9.

(Collected from Genesee, Alberta).



210



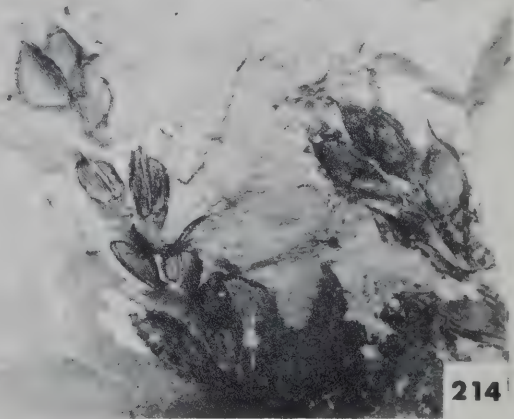
211



212



213



214

The flattened fruiting axes with the attached fruits do not help in interpreting the morphology of the carpels. (For details on this aspect, see Swamy and Bailey, 1949). Swamy and Bailey have shown that the "flower" of *Cercidiphyllum* is, in fact, a highly condensed inflorescence with practically no axis. If it is assumed that the fossil fruits borne on an elongated axis are cercidiphylloid in their morphology it follows that reduction of the axis has occurred during evolution. Until now there is no evidence of successive stages of evolutionary reduction. But it is interesting to note that in modern *Cercidiphyllum* the fruits are borne on a "reduced" short shoot and never on the long shoot. If the analogy of the reduction in the vegetative axis (short shoot) is extended, it is not improbable to visualize a reduction in the inflorescence axis also. This inference would lend support to the view that the fruits are cercidiphylloid in their affinity.

(Figured specimens bearing numbers S 990 (B), S 943, S 2842 (B), S 1009 and S 1547 were collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta).

Discussion: Classifications, in general, suffer from a considerable degree of arbitrariness. This subjective element becomes complicated when applied to fossils where one often deals with detached and isolated organs like foliage, fruits, etc.. As Just (1946) observes, "the value of taxonomic characters may not only vary from group to

group but also with different systematic categories....in difficult groups....new taxonomic characters must be found or known characters must be restudied in as many samples as possible....". Each investigator is forced to formulate his own criteria for various taxonomic designations (Brown, 1939; Hickey, 197-; Wolfe, 1966, 1968, p. 13; Dorf, 1969). As yet no extensive statistical data are available to lay down criteria for a generalized system of foliar classification. In this regard credit is due to Hickey's (197-) work on leaf "architectural patterns". An ideal system must take into account the range of variation which is basic to all biological material including leaves. Until such a system is devised the only recourse seems to be to investigate critically leaves of every species suspected of bearing a superficial resemblance to a fossil leaf. The information thus gained may then be used to interpret the taxonomic affinities of the fossil leaf. As applied to leaves, Wolfe (1968) lists a number of characters useful in classification. Among them, ultimate venation and marginal venation are considered by him as significant criteria at the generic level. Granted that this is a good working method based on the biological principle that vasculature is generally conservative, still there are instances where ultimate venation does not seem to be a good character for taxonomic purposes. Commenting on the value of venation as a taxonomic aid, Bailey and Nast (1944) emphasize that in *Drimys* and *Pseudowintera*, the vein patterns vary extensively in

different collections of the same species and in different leaves from the same plant. Figures 18 to 20, plate 3 (Bailey and Nast, 1944) are particularly instructive, showing the variation in ultimate venation, observed in *Drimys piperita* Hook., from different collections and different environments. A similar variation is found in *Cercidiphyllum japonicum*, where not only the nature but also the concentration of the vein islets (areoles) and the intruding veinlets vary in different types of leaves (pl. 12, figs. 82 to 84). A similar condition is observed in *C. magnificum*, where considerable difference between short and long shoot leaves is seen in the ultimate venation. Again, studies on the histogenesis of venation in *Liriodendron* by Pray (1955) have shown that differentiation of vein endings in areoles proceeds for a long time and that xylem maturation in vein endings is not completed till the leaf has reached maturity. In cleared leaves of *Cercidiphyllum* the vein islets show variable shapes and sizes on the same leaf at different locations. The only constancy, in shape and size, was observed in a limited area midway between the midrib and the margin at the widest portion of the leaf (Levin, 1929). Further, vein islets increase in size to a limited extent with the maturity of the leaf. This is borne out by the decreasing vein islet number with increase in area of the leaf (Table 10, long shoot). It is assumed here that a small leaf generally is an immature leaf. (No ontogenetic studies were made). The relevancy of these observations as

applied to fossils may be questioned, because identification of fossil leaves is dealt with on a morphological basis and it is impossible to tell whether a leaf is mature or immature. But these observations become relevant in evaluating the relative taxonomic value of the ultimate venation; especially, in view of Wolfe's recognition of "five different species" of *Cercidiphyllum* (Wolfe, 1966, p. B 9) among the variants of *Cercidiphyllum arcticum* (Heer) Brown (Brown, 1939, 1962) based solely on ultimate venation, and his generalization that, "This indicates that certainly five different species are represented" (Wolfe, 1966, p. B 9). It should be noted that Wolfe did not provide any statistical data or discuss the range of variation to substantiate his generalization. Further, he observes that the ultimate venation in *Trochodendroides serrulata* (Ward) Wolfe, is "strikingly different from that of the Recent *C. japonicum*.. ." (Wolfe, 1966, p. B 9). It is not known what type of cercidiphylloid venation was taken as the standard for comparison, because *C. japonicum* exhibits considerable variability in the ultimate venation depending upon the type of leaf chosen (pl. 12, figs. 82 to 84). The point here is that more data on the range of variation need to be presented before resorting to taxonomic oversimplification. If the nature of the ultimate venation is to be taken as the sole criterion for distinguishing two species, it fails in the case of modern *Cercidiphyllum japonicum* and *C. magnificum*. These two species cannot be distinguished on the

qualitative basis of ultimate venation, but can be readily distinguished on the basis of other characters. Again, if the venation patterns illustrated in figures 83 and 84 (pl. 12) belonging to two leaves of *C. japonicum* were to become fossilized two entirely different patterns of vein endings would result, i.e., the vein endings in figure 83 would be imprinted as thick strands, while those in figure 84 would be imprinted as thin wispy strands. If Wolfe's (1966) reasoning is applied, the two "fossilized" imprints would then be assigned to two different species. This hypothetical example has a direct bearing on Wolfe's distinction between *Trochodendroides serrulata* (Ward) Wolfe and *Dicthylophyllum richardsoni* (Heer) Wolfe the former showing 'thick-walled' vein islets and thick intruding veinlets; the latter showing "large areoles intruded by thin branching veinlets" (Wolfe, 1966, B10, fig. 1, B,C.). In fact, variability in the thickness of the ultimate vein endings as well as the 'walls' of vein islets was frequently observed within the three fossil species of *Cercidiphyllum*, viz., *C. genesevianum* sp. nov., *C. flexuosum* (Hollick) and *C. cuneatum* (Newberry) (for example, compare pl. 20, fig. 137 and pl. 21, fig. 143 of *C. flexuosum* and pl. 13, fig. 90 and pl. 19, fig. 128 of *C. genesevianum*). Further, some of the leaves of *C. flexuosum* (Hollick) were observed to have variable vein concentrations in the same leaf, i.e., different areas show different sizes of vein islets. Moreover, in fossil leaves, the ultimate vein endings are rarely preserved even in the

well-preserved material from Genesee, Alberta. This would be especially true if the vein ending is made up of a single tracheid. This factor becomes critical when two species are to be distinguished by simple or branched veinlets. A branched veinlet, when the ultimate terminations are not preserved, may be mistaken for a simple veinlet. The foregoing discussion and a detailed study of the foliar variation in *Cercidiphyllum* would seem to indicate that the nature of ultimate venation, as far as this genus is concerned, is a feature of limited value. What limited value the characteristic of ultimate venation has is apparent only when taken in conjunction with other characters. Of course, Wolfe (1966), who considers that the nature of ultimate venation as the diagnostic criterion outweighing all other foliar features in the identification of a species, could argue that a high degree of variation in ultimate venation is met with as an exception in primitive angiosperms (Bailey and Nast, 1944); and that such variation is not seen in more advanced species. This is of considerable significance to an investigator of Upper Cretaceous and Paleocene floras because of the greater likelihood of encountering primitive angiosperms exhibiting high levels of plasticity as one goes back into the geological past. The best method in this situation is to take many characters including minor venation and apply them as a group without giving special weight to any particular character. If a pair of characters are found to overlap, a statistical treatment may help. To

take a specific illustration, *C. japonicum* and *C. magnificum* exhibit the same type of ultimate venation (pl. 12, figs. 82 to 87). But they can be distinguished by their vein concentrations as measured by their mean vein islet numbers. Vein islets are smaller in *C. magnificum* than *C. japonicum*. Their mean vein islet numbers are 2.4 and 0.8 respectively.

In erecting the three species of *Cercidiphyllum* a qualitative as well as a quantitative approach was used. The various angles between the major veins that were chosen for morphological comparison, reflect the growth pattern of the leaves (Foster, 1952; Pray, 1955) presumably under genetic control. Whether this feature has any taxonomic significance remains to be tested. In spite of the overlapping ranges of the angles of major venation, differences are noticed between the species when the means of variables are considered (graphs 2 to 4). The full significance of these differences could be realized by comparative multivariate analysis, taking all the variables simultaneously. For the present, the data given in the appendix help in providing proper and precise description of the species. It should be emphasized that large collections are required for any kind of statistical analysis.

Comment has been made under each of the three fossil species of *Cercidiphyllum*, viz., *C. genesevianum*, *C. flexuosum* and *C. cuneatum* that some of the variants of the three species resemble fossil leaves assigned by various authors (Ward, 1887; Newberry, 1898; Berry, 1922, 1935; Hollick,

1936) to *Populus*, *Trochodendroides*, etc.. These species were all brought under *Cercidiphyllum arcticum* (Heer) Brown, by Brown in 1939. In the introduction reference has been made as to why Brown (1939) replaced the genus *Trochodendroides* with *Cercidiphyllum*. The stability and validity of *C. arcticum* (Heer) Brown was contested by Wolfe (1966). He erected three species, viz., *Cocculus flabella* (Newberry) Wolfe, *Trochodendroides serrulata* (Ward) Wolfe and *Dicotylophyllum richardsoni* (Hollick) Wolfe, and transferred some of Brown's (1939, 1962) synonymy included under *C. arcticum* into the new combinations. Reference has already been made that this splitting up of the *C. arcticum* assemblage was based primarily on the nature of ultimate venation (Wolfe, 1966, p. B 10, fig. 1). Assuming that Wolfe's generic transfers are valid it is strange that he transferred a number of specimens with a prominent toothed margin having glandular tips into *Cocculus*, a genus which has never been reported to have a non-entire (toothed) margin. No explanation was provided for expanding the generic range of *Cocculus* to include non-entire margined specimens, unless it is assumed that more weight was attached to ultimate venation than to the margin. If this inference is accepted the situation becomes more puzzling because Wolfe (1968, p. 13) emphasizes the significance of the margin, when he says, "In some species that have both a non-entire and an entire margin, the fact that this variation is present is fully as significant as the fact that a species always has a finely

serrate margin". As a corollary, it follows that an entire margin is significant if it is always shown by a species. Although it is not clear whether he was referring to fossil species or living species, the fact stands out that he transferred a number of non-entire margined specimens into *Cocculus*, a genus which always shows an entire margin without exception. This contradiction remains to be explained. The above discussion is relevant in the present context, because a number of entire-margined variants from the Genesee assemblage, included under *C. cuneatum* (Newberry), bear a strong resemblance to the variants of *C. arcticum* (Heer) Brown. If Wolfe's (1966) classification is followed, the entire-margined variants of *C. cuneatum* (Newberry) must find a place in *Cocculus flabella* (Newberry) Wolfe (Wolfe, 1966) and not in *Cercidiphyllum*. This problem has to be resolved and as far as *C. cuneatum* (Newberry) is concerned sufficient reasons have been advanced (refer above) as to why some of its entire-margined variants cannot be placed in *Cocculus*. Even if it is assumed that the entire-margined fossils are cocculoid in their affinity, independent evidence from reproductive structures does not substantiate such an assumption. The reason for this is that one might expect to find some evidence of fruits and seeds of *Cocculus* in a locality where supposed *Cocculus* leaves are so abundant. Of course, it must be admitted that there is a reasonable explanation for the absence of fruits because the fruits of *Cocculus* are berries which may not be preserved. The only

fruits discovered so far as the ubiquitous cercidiphylloid type. Therefore, until cocculoid type of fruits are found it can be inferred that *C. cuneatum* (Newberry) is cercidiphylloid and not cocculoid in its affinities. There is also indirect evidence by way of ecological association. It has been recorded by Chu and Cooper (1950) that *Cercidiphyllum* is an ecological associate of *Metasequoia glyptostroboides* Hu and Cheng. It is interesting to note that *Metasequoia* is a major element (36%) next to *Cercidiphyllum* (43%), in the Genesee assemblage.

The three species *C. genesevianum* sp. nov., *C. flexuosum* (Hollick) and *C. cuneatum* (Newberry) are morphological species. They may coincide with real species in the biological sense or they may not. They may actually represent infraspecific categories. If the latter view is held problems of nomenclature will arise because varietal names have to be appended to specific epithets. While it is perfectly valid to indulge in such academic hair-splitting, its utility is doubtful. It would only result in the addition of lengthy names to literature which is already overburdened.

A further interesting observation is the occurrence of only one type of fruit, while three species of leaves are found in about equal frequencies. Two interpretations are possible here, i.e., (1) either all three species produced similar fruits or (2) the classification into three species is artificial while in fact there is only a single species producing one kind of fruit. To refute the latter view,

sufficient morphological evidence has been presented to demonstrate the recognition of three species; as for the presence of only one kind of fruit, evidence from living species of *Cercidiphyllum* is instructive. Modern *C. japonicum* and *C. magnificum* both bear fruits which are hardly distinguishable except for size. So it is quite possible that all three fossil species produced similar fruits. At present, it is not possible to assign the fruits to any single species since organic connection between the fruits and leaves is lacking.

Evolution of *Cercidiphyllum*: Reference has been made regarding the varying degrees of similarity between the three fossil species of *Cercidiphyllum*, and the modern species. Thus, *C. genesevianum* is similar to the long shoot and sucker shoot leaves of *C. japonicum*; *C. flexuosum* (Hollick) bears resemblance to the short shoot leaves of *C. japonicum* and *C. magnificum*; some of the non-entire margined variants of *C. cuneatum* (Newberry) show similarities with the long shoot and short shoot leaves of *C. magnificum*, especially in marginal configuration; a few of the variants of *C. cuneatum* show widely separated rounded serrations (pl. 25, fig. 170; pl. 27, fig. 186) resembling in this feature the seedling leaves of *C. japonicum* (Swamy and Bailey, 1949, p. 188, fig. 1, b). A comment was also made that the growth pattern of *C. flexuosum* (Hollick) appears to be different from the short shoot leaves of modern *C. japonicum*. It was observed in *C. japonicum* that even the smallest leaf measuring only a

few millimeters long has a well-developed, cordate base. In *C. flexuosum* a truncate or incipient cordate base (base 180°) was observed only in leaves with an area of 2000 sq mm or more (Table 16, append.). On the other hand, leaves with a base less than 180° show a more uniform distribution starting from a very small leaf (Table 16, append. pl. 20, fig. 136). Failure to observe a leaf with a truncate or incipient cordate base having an area less than 2000 sq mm may be due to a number of factors. First, the sample may not have been large enough to include small cordate forms. Though pertinent, this can be ruled out immediately because, very small leaves with areas less than 300 sq mm have been found in *C. cuneatum*, *C. genesevianum*, and in *C. flexuosum* as mentioned above. An alternative and more probable view is that the cordate base develops after the leaf has attained certain dimensions. If this inference is accepted, then some of the small leaves with a cuneate or rounded obtuse base may represent growth stages of the ovate or wide ovate leaves with a truncate or incipient cordate base. This type of growth pattern in which a leaf with an incipient cordate base passes through a prolonged developmental stage, having an obtuse base, is different from the development of the short shoot leaf of *Cercidiphyllum*. The short shoot leaf does not seem to go through a prolonged stage with an obtuse base, because the smallest leaf observed was found to have a fully developed cordate base. This interpretation is purely observational, inferred from herbarium material; ontogenetic

studies should throw light on this aspect.

In any event, Table 16 (append.), indicates that *C. flexuosum* possessed a dimorphic foliage, one with an obtuse or cuneate base and the other with truncate or incipient cordate base.

Modern *Cercidiphyllum japonicum* produces long and short shoot leaves regularly, which, though dissimilar in a number of features, possess some characters in common. Applying the analogy of long and short shoot leaves to the fossil species a single species could be visualized bearing leaves assigned to *C. genesevianum* and *C. flexuosum* (Hollick), because of their respective strong similarity to the long shoot and short shoot leaves of *C. japonicum*. But there are a few insurmountable problems which do not support such a view. *C. genesevianum* and *C. flexuosum* differ significantly in a number of features, and any overlapping of characters between the two is insignificant. So it is safe to assume that they are distinct species or infra-specific categories evolving independently. As gathered from published data, some of the variants of *C. genesevianum* show a superficial resemblance to a few elongate, ovate variants of *C. elongatum* Brown, which according to Brown (1939, p. 495) "developed during the middle or late Eocene" and survived "until probably upper Oligocene or lower Miocene". Becker (1960) later reported the same species from lower Eocene strata. *C. elongatum* was not precisely defined by Brown (1939). Information regarding its foliar morphology had to

be pieced together from various publications (Wolfe, 1968, p. 19; Brown, 1939). After considering the information making possible the comparison of *C. elongatum* with *C. genesevianum* it became apparent that the two species are not conspecific. Such a possibility is also ruled out independently, if it is assumed that *C. genesevianum* had an earlier origin, judging from other species present in the Genesee fossil flora, than the earliest occurrence of *C. elongatum* elsewhere. On the other hand, it is probable that *C. genesevianum* has evolved into *C. elongatum*. It is also probable that *C. flexuosum* (Hollick) might have independently evolved into *C. crenatum* (Unger) Brown by Eocene times in the north polar regions (Brown, 1939). It should be noted here, that the variants of *C. flexuosum* having an incipient cordate base, are similar in general form and major venation to *C. crenatum*, except that *C. crenatum* has a pronounced cordate base, as is found in the short shoot leaves of modern *Cercidiphyllum japonicum*. There is also a considerable difference in dentition between *C. flexuosum* and *C. crenatum*. If this view is tentatively accepted, then it follows that the modern *C. japonicum* is a product of hybridization between *C. elongatum* and *C. crenatum*. Where and when the hybridization might have occurred cannot be answered in the absence of extensive fossil collections of a high quality.

It is fully realized that the above view is built upon many assumptions and speculations. The object of this hypothesis is to raise questions, and put forth an alternative

view against that of Brown (1939) who traced a step-wise stratigraphical evolution of *Cercidiphyllum*, from *C. ellipticum* (Upper Cretaceous) to *C. japonicum* (Recent) through the intermediate stages, viz., *C. arcticum* (Paleocene to Eocene), *C. elongatum* (middle Eocene to lower Miocene) and *C. crenatum* (middle Eocene-Oligocene-upper Miocene). Brown (1939) assumes a single lineage for *Cercidiphyllum* whose evolution from Upper Cretaceous to the Recent is correlated with a progressive change in over-all leaf shape. A study of Genesee material would indicate that *C. arcticum* (Heer) Brown, the predominantly Paleocene to middle Eocene species is a mixed assemblage of three distinct species. The demonstration of the occurrence of three distinct species in the lower Tertiary is not in accordance with Brown's view. Moreover, a few inconsistencies in Brown's paper (1939) would contradict his view on the course of evolution of *Cercidiphyllum* as a single lineage. According to Brown (1939, p. 496) *C. arcticum* and *C. crenatum* may be partly contemporaneous in the north polar regions. Brown also suggested that *C. crenatum* had an earlier origin in the upper latitudes than in the lower latitudes. If these ideas are true then one must assume, first that *C. crenatum* has evolved directly from *C. arcticum* without going through the intervening species, viz., *C. elongatum*, in the upper polar regions; second that *C. crenatum* has evolved as early as the Eocene, in the upper latitudes (Hollick, 1936), and spread to the lower latitudes by upper Oligocene and lower Miocene

because *C. crenatum* has not been reported to occur in pre-Oligocene strata in the lower latitudes. If this view is not accepted, then one must assume that *C. crenatum* had two independent origins, one in the lower latitudes (Bridge Creek, Oregon) in upper Oligocene or lower Miocene and another earlier origin in the Eocene times in the polar regions. The likelihood of the same species developing independently in two disparate geological times spanning millions of years, is highly improbable. It is also difficult to visualize the independent origin of *C. crenatum* through different lineages, one arising from *C. arcticum*, passing through *C. elongatum* and culminating in *C. crenatum*, the other arising directly from *C. arcticum* without passing through *C. elongatum*. These inconsistencies could be avoided if the hypothesis of hybridization proposed above is tentatively accepted. The view of hybridization is not new (Stebbins, 1948, 1950, 1959). Unfortunately no information is available on the cytology of the modern species of *Cercidiphyllum* except for the fact that *C. japonicum* has 19 chromosomes (Whitaker, 1933).

Foliar dimorphism in *Cercidiphyllum japonicum* has been explained on the basis of ontogeny. Briefly stated, short shoot leaves go through a longer embryonic period from the time of initiation of growth to maturity while long shoot leaves go through a shorter growth period, which is completed in one season. This fails to explain the intermediate nature of sucker shoot leaves showing features of

both long and short shoot leaves. Sucker shoot leaves like long shoot leaves presumably complete their growth in one continuous period. (For full details see Titman and Wetmore, 1955; Critchfield, 1960). Though these papers put forth a reasonable explanation for the mechanism of occurrence of dimorphic foliage, they do not throw any light on the phenomenon itself, i.e., in the sense of adaptation, phylogeny and evolution. There is as yet no detailed information on the adaptive values of foliar forms, venation, dentition, etc.. Further research in this line may clarify some of the problems raised in this part of the discussion.

No comment can be made at the present time on *C. cuneatum* (Newberry), and its phylogeny. The origin of the three fossil species is unknown.

Some of the variants of *C. genesevianum* sp. nov. with a rounded obtuse base resemble *C. ellipticum* (Newberry) Brown, (Dorf, 1942, p. 141, pl. 10, fig. 4), the predominantly Upper Cretaceous species. Variants of *C. flexuosum* (Hollick) n. comb. match Upper Cretaceous species like *Populus pseudoelliptica* Hollick (Hollick, 1930, p. 63, pl. 31, fig. 6) and *Cercidiphyllum arcticum* (Shoemaker, 1966, p. 68, pl. 14, fig. 2). Variants of *C. cuneatum* (Newberry) n. comb. resemble Upper Cretaceous species like *Trochodendroides rhomboideus* (Lesquereux) Berry (Berry, 1922, p. 166, pl. 36, fig. 5). This seems to indicate that the three fossil species, *C. genesevianum* sp. nov., *C. flexuosum* (Hollick), *C. cuneatum* (Newberry), are established as

independent taxa even in the Upper Cretaceous.

Occurrence: Of the three species, *C. cuneatum* (Newberry) appears to be the most common in Upper Cretaceous-Paleocene (up to lower Eocene in some instances) formations in the eastern part of the United States, Canada and circum-polar regions. Occurrence of *C. flexuosum* (Hollick) contemporaneous with *C. cuneatum* appears to be rare as inferred from published data, but interestingly its frequency is high in the Genesee collection. Its rare occurrence in other Upper Cretaceous-lower Tertiary formations might be due to the difficulty in recognizing it from some of the variants of *C. cuneatum*. A marked similarity is seen between the two in general form and to some extent major venation; under poor preservational conditions, especially in minor venation and margin, they can hardly be separated. Species assignable to *C. genesevianum* are very rarely met with in literature dealing with Upper Cretaceous-Paleocene floras, and this also might be partly due to its similarity, in over-all form, to some of the variants of *C. cuneatum*, under conditions of poor preservation.

No final word can be said about the phylogeny of *Cercidiphyllum*. There are still a few thorny problems requiring answers. For instance, the connection of the fruits to the foliage, and the supposed reduction of the fruiting axis. When did the fruits borne on an elongated axis become reduced? Hopefully more studies of extensive collections should throw light on these problems.

Family: Platanaceae*Platanus raynoldsii* Newberry

(Pl. 33, figs. 216 to 221)

Description: Leaves mostly chartaceous, rarely coriaceous; shape ovate in smaller leaves, tri-lobed in larger leaves; the lateral lobes may or may not be pronounced (pl. 33, figs. 216, 217, 219); apex acute; margin undulate-glandular with shallow scalloped sinuses; teeth, gland-tipped; glands, emergent almost mucronate (pl. 33, fig. 218, arrows); base, obtuse, truncate to incipient cordate; major venation palmate, with a straight midrib and one pair of suprabasal primaries of equal strength flanking the midrib; primaries subopposite, straight, craspedodromous extending into the lateral lobes, diverging, and making an angle of 70-80°; secondaries from the midrib, 6 to 7 pairs opposite, subopposite, or alternate, making an angle of 40-45° with midrib; secondaries from the midrib, craspedodromous proximally, grading into a semi-craspedodromous condition distally; distal secondaries weak forming angular loops; outer secondaries from primaries craspedodromous proximally, grading into semi-craspedodromous condition distally; proximal outer secondaries almost at right angles to the midrib, making an angle of 45-50° with the primary; tertiaries percurrent, vein islets large, polygonal, regular with a mean vein islet number of 1.0, with branched veinlets intruding the vein islets (pl. 33, fig. 221). Some

specimens show mesophyll-configurations (pl. 33, fig. 220), which are very small in size, with a mean diameter of $30\ \mu$.

Comment: Twenty specimens in the collection comprise this species. The leaves are large the largest being 230 mm long and 235 mm wide, with an area of approximately 36,000 sq mm (pl. 33, fig. 216). The generic designation is well established judging from the literature on lower Tertiary floras of western United States (Brown, 1962). Among the living species of *Platanus* the Genesee material exhibits a strong resemblance to *Platanus cuneata* Willd. (= *orientalis*) in margin, shape, and major venation. The size of the mesophyll lacunae of this species with a mean diameter of $26\ \mu$ (*Platanus cuneata* Willd. U.S.N.M. Herbarium sheet 54956) agrees closely with that found in the Genesee specimens. The nature of mesophyll-configurations has been discussed under Cercidiphyllaceae. The only difference between *Platanus raynoldsii* and *P. cuneata* seems to be in the mean vein islet number. *Platanus cuneata* Willd. shows a mean vein islet number of 4.0, while *P. raynoldsii* Newberry, shows a mean vein islet number of 1.0. These figures are based on very few specimens. It is doubtful if these numbers represent the true range of variation.

Brown (1962) lumped a number of species, assigned to various genera, under *Platanus raynoldsii* Newberry. Some of the species included under his synonymy could almost be duplicated with some of the Genesee specimens. Hence the Genesee fossils are made conspecific with *P. raynoldsii*.

It should, however, be noted that the mesophyll-configurations in this species were discovered for the first time from the Genesee material. This feature has not been reported in the literature so far. Some of the fossil species which bear a strong resemblance to Genesee specimens are: *Platanus raynoldsii* Newberry (Newberry, 1898, p. 109, pl. 35; Knowlton, 1930, p. 77, pl. 35; Bell, 1949, p. 59, pl. 37, fig. 2, pls. 38 to 41; Brown, 1962, p. 64, pl. 30, figs. 1 and 3, pl. 31, fig. 6), *Platanus aceroides* Göppert (Knowlton, 1917, p. 321, pl. 63, fig. 4, pl. 97, figs. 2 and 3), *Platanus aceroides cuneata* Knowlton n. var. (Knowlton, 1917, p. 321, pl. 113, fig. 1), *Platanus aceroides latifolia* Knowlton n. var. (Knowlton, 1917, p. 321, pl. 93, fig. 3), *Platanus guillelmae* Göppert (Ward, 1887, p. 37, pl. 20, fig. 1; Knowlton, 1930, p. 76, pl. 34, fig. 1), *Platanus haydenii* Newberry (Newberry, 1898, p. 103, pl. 36, pl. 56, fig. 3; Knowlton, 1930, p. 79, pl. 36, fig. 1), *Platanus nobilis* Newberry (Newberry, 1898, p. 106, pl. 37, fig. 1), *Platanus? regularis* Knowlton (Knowlton, 1917, pl. 113, fig. 4), *Acer trilobatum tricuspidatum* (Braun) Heer (Ward, 1887, p. 66, pl. 29, figs. 3 and 4), *Aralia? serrata* Knowlton (Knowlton, 1917, p. 341, pl. 108, fig. 4), *Cissus grossedentata* Knowlton (Knowlton, 1917, p. 340, pl. 104, Fig. 1), *Grewiopsis populifolia* Ward (Ward, 1887, p. 90, pl. 40, fig. 3), *Populus nervosa* Newberry (Newberry, 1898, p. 48, pl. 27, figs. 2 and 3), *Rhus? viburnoides* (Knowlton, 1917, p. 328, pl. 98, fig. 5) and *Viburnum lakesii*

Plate 33.

Fig. 215. *Tapiscia serrata* (Newberry) n. comb.

(S 328) X 0.5.

Figs. 216-221. *Platanus raynoldsii* Newberry

Fig. 216. (S 981 (A)) X 0.4.

Fig. 217. (S 796 and S 801) X 0.5.

Fig. 218. Apical glands on teeth indicated by arrows.

(S 2713 (B)) X 2.7.

Fig. 219. (S 2713 (B)) X 0.5.

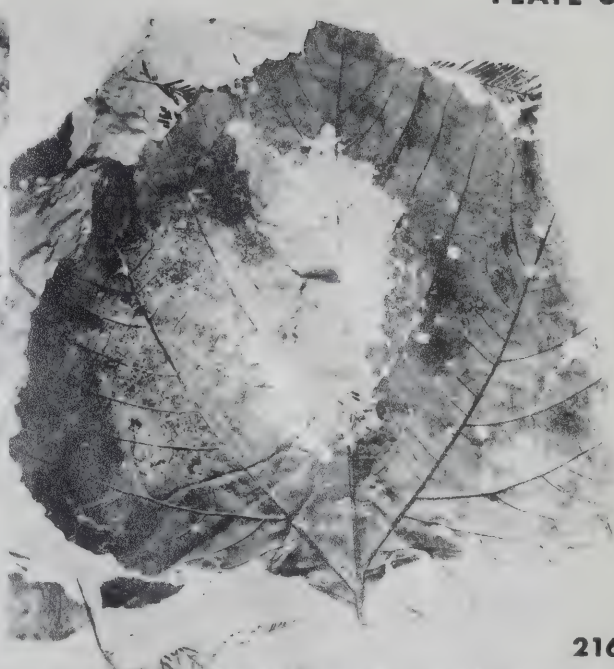
Fig. 220. Mesophyll-configurations. (S 169 (L)) X 22.

Fig. 221. Minor venation. (S 3158 (B)) X 11.

(Collected from Genesee, Alberta).



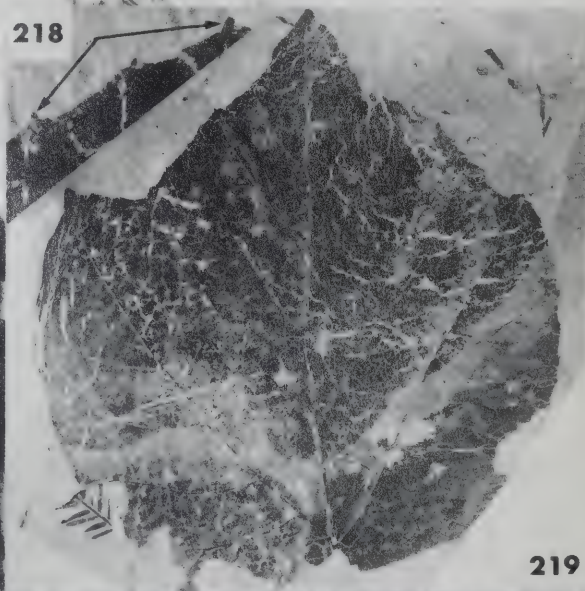
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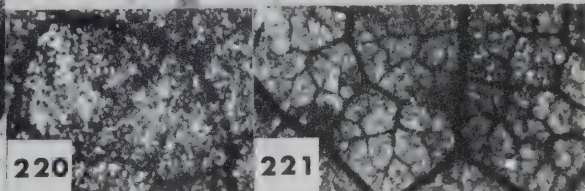


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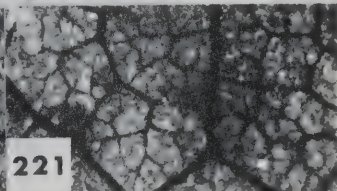


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221

Lesquereux (Knowlton, 1917, p. 348, pl. 110, fig. 4; Bell, 1949, p. 78, pl. 58, fig. 1).

(Figures specimens bearing numbers S 981 (A), S 796 and S 801, S 2713 (B), S 169 (L) and S 3158 (B) were collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta).

Family: Staphyleaceae

Tapiscia serrata (Newberry) n. comb.

(Pl. 33, fig. 215; pl. 34, figs. 224 to 226; pl. 35, figs. 227 to 230)

Alnus serrata Newberry (Newberry, 1898, p. 66, pl. 33, fig. 11)

Description: Leaves petiolate; texture chartaceous, coriaceous; shape, elliptic, or ovate with a mean L/W ratio of 1.5; tip acute; base obtuse, or incipient cordate; margin serrate to coarse-dentate, with a mean of 1.5 teeth per cm, acute, gland-tipped; sinuses angular, or rounded, regular; major venation pinnate, midrib straight with a mean of 10 pairs of secondaries, diverging at a mean angle of 50° from the midrib, alternate, irregularly spaced, straight or slightly zig zag, distal secondaries slightly curved; secondaries semi-craspedodromous, branching at acute angles near the margin, forming angular loops with successive secondaries; branches from secondaries very rarely form tertiary loops at the widest portion of lamina; a short vein enters a tooth either from a secondary or tertiary loop; a

short branch arising from the vein entering the tooth, extends to the superadjacent sinus; in the distal portions of the lamina the secondaries rarely craspedodromous; tertiaries weakly percurrent, straight or sinuous.

Comment: Fifty-four fossil leaves including 27 recognizable fragments were studied. The ultimate venation is rarely preserved except in a single fragment (S 2834, from Genesee, Alberta). In this specimen, patches of ultimate venation were observed; the vein islets are small with a mean vein islet number of 4. Veinlets intruding the vein islets were not seen. It was not possible to determine with certainty whether the absence of veinlets was a specific character or was due to poor preservation. The leaves are large with a mean area of 5300 sq mm, and the largest leaf is 220 mm long and 150 mm wide with an area of 22,000 sq mm (S 1326, from Genesee, Alberta). The fossil leaves of *T. serrata* resemble those of modern *Eucommia ulmoides* Oliv. superficially in form and dentition. But the major venation pattern is markedly different in *Tapiscia serrata*. In *Eucommia* the secondaries branch distally and form tertiary and quarternary loops near the margin, while in *Tapiscia serrata* even tertiary looping is rarely seen. On the other hand, a strong resemblance is seen between the variants of *Tapiscia serrata* (Newberry) and modern *Tapiscia sinensis* Oliv. an Asiatic species. A variety of this species, viz., *T. sinensis concolor* Cheng is an ecological associate of *Metasequoia glyptostroboides* Hu and Cheng (Chu

and Cooper, 1950). A comparison of a cleared leaf of *Tapiscia sinensis* (pl. 34, fig. 222; Wilson, U.S.N.M. Herbarium 596958) and *Tapiscia serrata* (Newberry) (pl. 34, fig. 225; pl. 35, fig. 228) illustrates the strong similarity in venation and general form between the two. (Compare also pl. 34, fig. 223 and fig. 224 showing marginal venation). The vein islet number in *Tapiscia sinensis* Oliv. is 2.5. This number is based on a single specimen.

A number of fossil species, like *Eucommia serrata* (Newberry) Brown (Brown, 1962, p. 72, pl. 44, figs. 1, 4, 5; pl. 45, figs. 3, 5), *Celastrus ferrugineus* Ward (Ward, 1887, p. 78, pl. 34, fig. 2), *Celastrus taurinensis* Ward (Ward, 1887, p. 79, pl. 34, fig. 6), *Celastrus ovatus* Ward (Ward, 1887, p. 81, pl. 36, fig. 1), *Celastrus alnifolius* Ward (Ward, 1887, p. 80, pl. 35, fig. 1), and *Viburnum finale* Ward (Ward, 1887, p. 115, pl. 57, fig. 5) bear resemblance to *Tapiscia serrata* (Newberry). It may be noted that a specimen designated by Brown as *Eucommia serrata* (Newberry) Brown (Brown, 1962, p. 72, pl. 44, fig. 4) is almost identical to a specimen of *Tapiscia serrata* (Newberry) illustrated in plate 35 (fig. 228).

(Figured specimens bearing numbers, S 328, S 1054, S 838 (A), S 266, S 847 (B), S 1591, S 248 and S 945 were collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta.)

Plate 34.

Figs. 222. *Tapiscia sinensis* Oliv.. Cleared leaf. For
comparison with fig. 225. (Slide # 128) X
1.5.

Fig. 223. Portion of the cleared leaf in fig. 222
showing details of venation and dentition for
comparison with fig. 224. X 2.

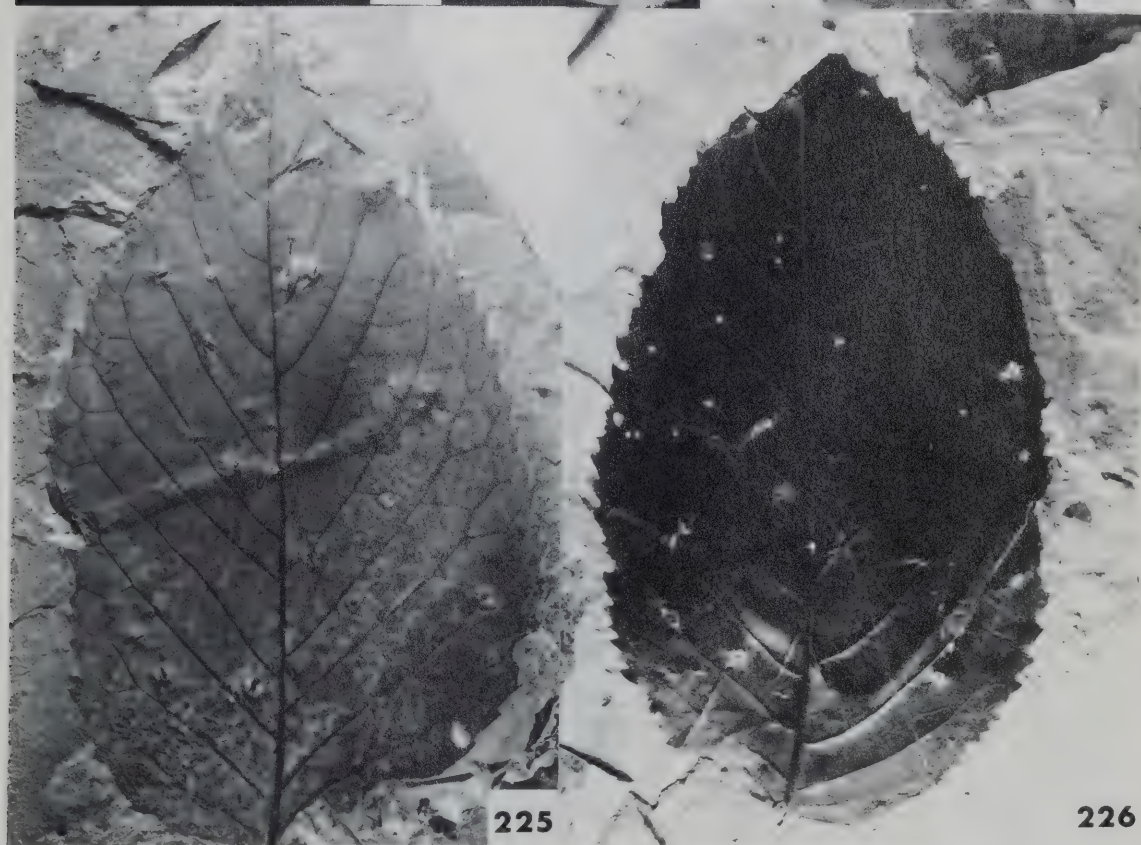
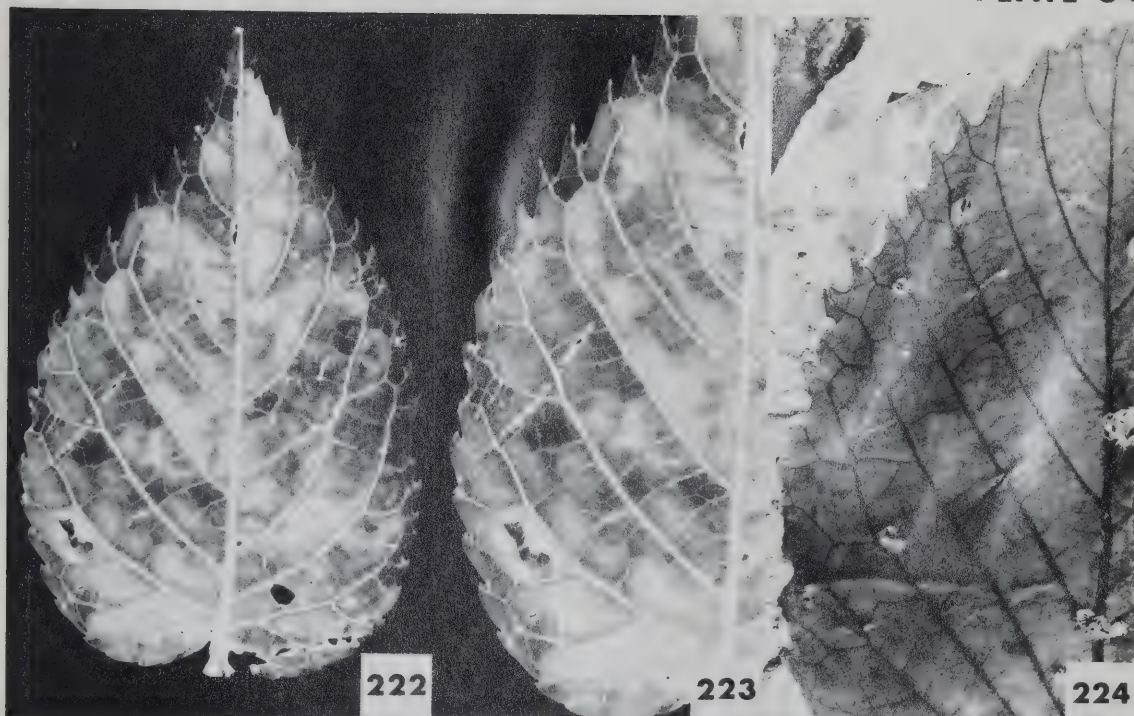
Figs. 224-226. *Tapiscia serrata* (Newberry) n. comb..

Fig. 224. (S 1054) X 1.1.

Fig. 225. (S 838 (A)) X 1.2.

Fig. 226. (S 266) X 0.8.

(Specimens shown in figs. 224-226 were
collected from Genesee, Alberta).



145.

Plate 35.

Figs. 227-230. *Tapiscia serrata* (Newberry) n. comb..

Fig. 227. (S 847 (B)) X 1.

Fig. 228. (S 1591) X 1.

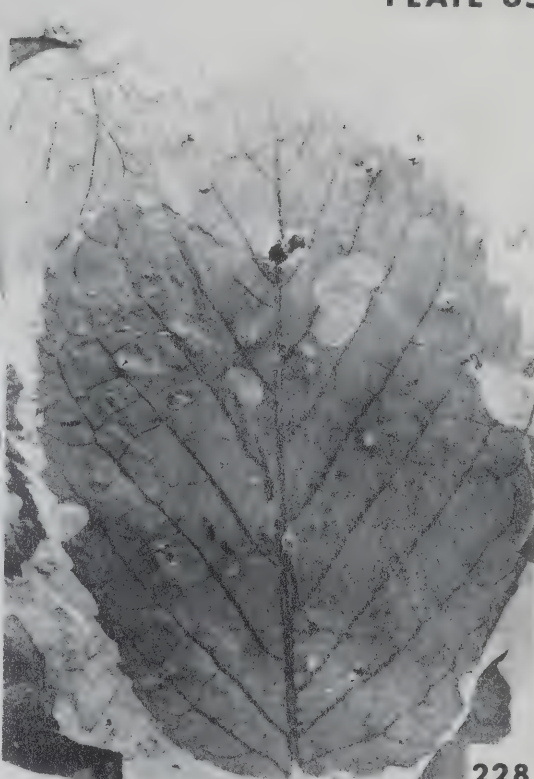
Fig. 229. (S 248) X 1.6.

Fig. 230. (S 945) X 1.

(Collected from Genesee, Alberta).



227



228



229



230

Family: Vitaceae*Vitis* sp.

(Pl. 36, figs. 231 to 235; pl. 37, fig. 236)

Description: Leaves petiolate; texture usually chartaceous, rarely coriaceous; shape ovate (pl. 36, figs. 231, 232) or tri-lobed (pl. 36, figs. 233, 234; pl. 37, fig. 236), margin compound toothed, with regularly spaced, large dentate teeth which are themselves serrate (pl. 36, fig. 234; pl. 37, fig. 236); teeth gland-tipped; glands, apical; base in well-preserved specimens, peltate, with two short basal lobes (pl. 36, figs. 233, 234); major venation palmate with a straight midrib, and two or three pairs of primaries flanking the midrib; inner primaries of equal strength to midrib, outer primaries weakest; inner primaries ascending, arcuate, making a mean angle of 80° between them, craspedodromous, ending in lobes, when the lobes are pronounced (pl. 36, figs. 233, 234; pl. 37, fig. 236); all primaries craspedodromous; secondaries arising from the midrib distal, curving up, craspedodromous grading into a semi-craspedodromous condition distally; outer secondaries arising from the primaries craspedodromous; tertiaries percurrent, straight, obarcuate; quarternaries arising distally from secondaries near the margin form angular loops; minor venation poorly preserved, except in a few specimens (pl. 36, fig. 235); vein islets small with a mean vein islet number of 5.0, with simple or once-branched veinlets intruding the vein islets.

Comment and discussion: *Vitis* sp. comprises 22 specimens of

the collection including recognizable fragments. The leaves are large with a mean area of 4400 sq mm based on 10 specimens. The largest leaf is 120 mm long and 90 mm wide with an area of 7200 sq mm (S 320 (L) from Genesee, Alberta).

The fossil variants resemble species of *Vitis* in overall morphology, particularly in the presence of a peltate base and basal lobes. Among the fossil species of early Tertiary age, a close similarity is seen between *Vitis olriki* Heer (Brown, 1962, p. 82, pl. 27, fig. 10) and figure 236 (pl. 37) in general morphology and venation. Leaves of *Vitis olriki* Heer are ".....obscurely lobed; borders dentate" (as quoted in Lesquereux, 1878, p. 241, pl. 41, fig. 8). Again, Knowlton (1917) commenting on Lesquereux's (1878) specimen states that the American specimen is "coarser toothed" as compared to Heer's specimens. Brown describes the species as having "entire or toothed margins" (Brown, 1962, p. 82). Koch (1963, p. 61) in his discussion of *Vitis olriki* Heer says that "much preparation had still to be done in the marginal zone" of Heer's type specimen. He also adds that Heer's type is incorrectly drawn regarding marginal serration. In any event, the fossil variants collected from Genesee consistently exhibit a compound toothed margin as already described above. The material is too scanty to decide the significance of the compound toothed margin as a diagnostic specific character. The state of preservation of the margin of the material assigned by various authors (see Brown's synonymy, 1962, p. 82) to *Vitis olriki* Heer is not known.

148.

Plate 36.

Figs. 231-235. *Vitis* sp..

Fig. 231. (S 880 (A)) X 1.3.

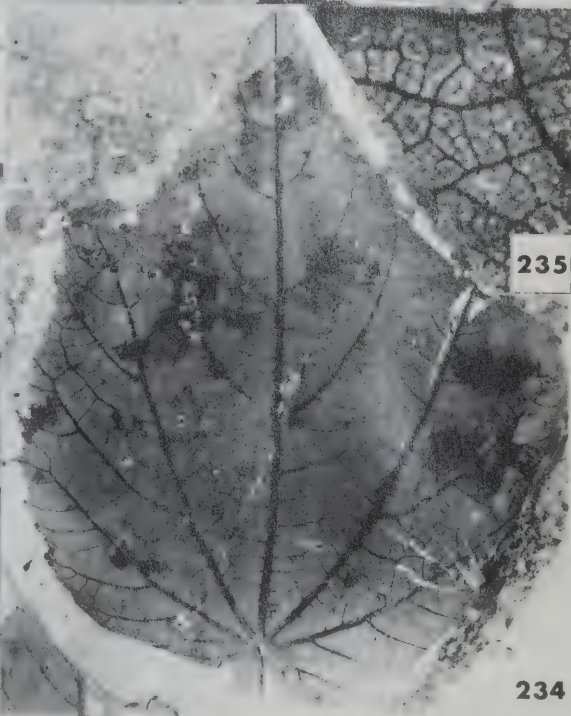
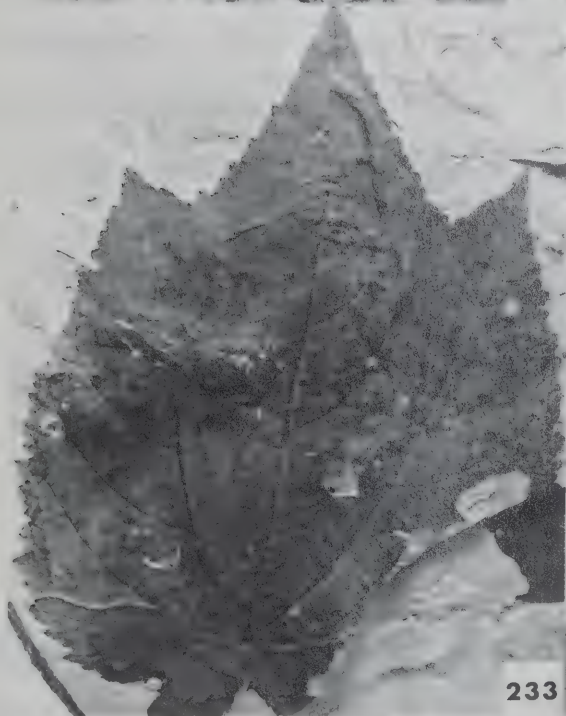
Fig. 232. (S 1078 (B)) X 0.8.

Fig. 233. (S 1325) X 0.8.

Fig. 234. (S 320) X 0.8.

Fig. 235. Minor venation. (S 1037) X 11.

(Collected from Genesee, Alberta).



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This comment is of some significance as applied to Genesee material because, if the small serrations present on the larger teeth are not preserved in the Genesee material then the variants would fall within the description of *Vitis olriki* Heer, showing a "coarser toothed" margin (Knowlton, 1917). Data on the range of variation exhibited by modern species of *Vitis* is not available at present for a thorough comparison between the fossil variants and their probable modern correlatives. In the absence of such data the significance of the margin as a taxonomic criterion cannot be assessed. Without a satisfactory evaluation of the margin, the Genesee variants of *Vitis* sp. could not be made conspecific with *Vitis olriki* Heer, in spite of the strong over-all similarity between them.

(Figured specimens bearing numbers S 880 (A), S 1078 (B), S 1325, S 320 and S 1022 (B) were collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta.)

Ampelopsis acerifolia (Newberry) Brown

(Pl. 37, figs. 237 to 239)

Description: Texture chartaceous; shape, tri-lobed; base truncate or incipient cordate; margin toothed, teeth large or of unequal size, rounded with concave rounded sinuses, rarely angular sinuses, teeth gland-tipped; glands, apical; major venation palmate with a straight midrib flanked by two or

three pairs of primaries; inner primaries strongest, divergent straight, making a mean angle of 70° between them, craspedodromous ending in lobes (pl. 37, figs. 237-239); all primaries basal in origin and craspedodromous; secondaries arising from the midrib straight, divergent, craspedodromous; outer secondaries arising from the primaries craspedodromous; tertiaries percurrent, straight, obarcuate; quarternaries originating distally from the secondaries near the margin form angular loops. Preservation of minor venation poor; where preserved, vein islets are polygonal intruded by freely ending branched veinlets; mesophyll-configurations seen at a few isolated areas in one specimen (pl. 37, fig. 238) and the configurations are extremely small, with a mean diameter of 15μ .

Comment: Variants of *Ampelopsis acerifolia* (Newberry) Brown, comprise 29 specimens of the collection. The mean size based on 11 specimens is 3500 sq mm in area, the smallest being 45 mm long and 40 mm wide (S 864 (L) from Genesee, Alberta and the largest being 87 mm long and 95 mm wide (S 387, from Genesee, Alberta). The small mesophyll-configurations, observed in a single specimen (pl. 37, fig. 238) are similar to the mesophyll lacunae found in a cleared leaf of *Parthenocissus* (*Ampelopsis*) *tricuspidata* (Sieb. and Zucc.) Planchon. The nature of the mesophyll-configurations has already been discussed under *Cercidiphyllaceae*. A number of fossil species assigned to various genera could be matched with some of the variants collected from Genesee, Alberta.

151.

Plate 37.

Fig. 236. *Vitis* sp.. (S 1022 (B)) X 1.4.

Figs. 237-239. *Ampelopsis acerifolia* (Newberry) Brown.

Fig. 237. (S 790) X 1.

Fig. 238. (S 930) X 1.

Fig. 239. (S 958 (A)) X 1.

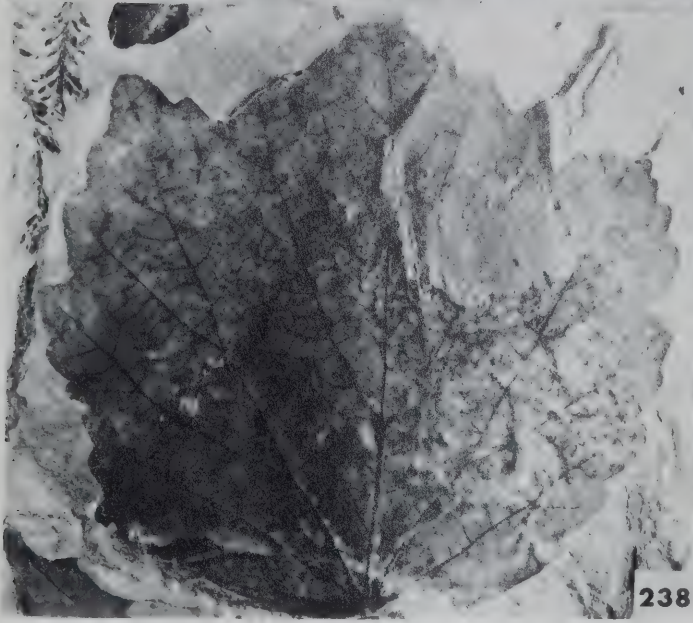
(Collected from Genesee, Alberta).



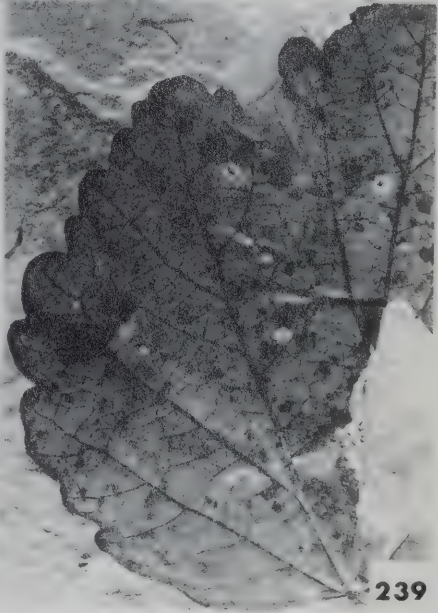
236



237



238



239

For example, Newberry's description of *Populus acerifolia* Newberry (Newberry, 1898, p. 37, pl. 28, figs. 5 to 8) can be exactly matched with figure 237 (pl. 37). Brown (1962) synonymized a number of fossil species under his new combination *Ampelopsis acerifolia* (Newberry) Brown. Some of his figured specimens (Brown, 1962, p. 78, pl. 51, figs. 3, 13, 16, 17) are nearly identical with the Genesee variants. Other fossil species showing similarity with the Genesee fossils are: *Acer arcticum* Heer (Bell, 1949, p. 71, pl. 48, fig. 2), *Cissus lesquereuxii* Knowlton (Knowlton, 1930, p. 114, pl. 48, fig. 3), *Dombeyopsis nebrascensis* (Newberry) Bell (Bell, 1949, p. 62, pl. 20, fig. 1), *Vitis bruneri* Ward (Ward, 1887, p. 69, pl. 32, figs. 1, 2), *Vitis carbonensis* Ward (Ward, 1887, p. 70, pl. 32, fig. 3).

(Figured specimens bearing numbers, S 790, S 930 and S 958 (A), were collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta.)

Incertae sedis

Class: Angiospermae

The systematic affinities of the specimens figured in plate 38, are unknown at present. They are discussed separately as follows:

Pl. 38, fig. 240

Two specimens were recovered from the collection. The figured specimen is 90 mm long and 50 mm wide, ovate with a rounded base; margin is rounded serrate with a gland at the

apex; major venation is pinnate with eight pairs of secondaries making a mean angle of 50° with the midrib, semi-craspedodromous, each secondary forming loops with the superadjacent secondary, near the margin; a single veinlet enters each tooth from each loop. Tertiaries are almost at right angles to the midrib at the widest portion of the leaf. Minor venation is poorly preserved.

These specimens resemble *Tapiscia serrata* (Newberry) described elsewhere in this thesis, in major venation, but the dentition is distinct in being rounded serrate. It also bears resemblance to a specimen figured by Brown assigned to *Eucommia serrata* (Newberry) Brown (Brown, 1962, p. 72, pl. 45, fig. 1).

(Figures specimen bearing number S 1073 was collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta.)

(Pl. 38, fig. 241)

Only two specimens comprise this foliar form. The unfigured specimen is a fragment (S 1017 (B)). The leaf is chartaceous, ovate, 98 mm long and 77 mm wide, irregularly dentate, with a deeply cordate base. This feature is not very well seen in the figure. Major venation is strongly zig zag, palmate, inner primaries divergent making an angle of 60° between them forming angular loops with the first outer secondaries arising from the first secondaries of the midrib. Outer secondaries arising from the inner primaries

form successive angular loops with each other. Minor venation, where preserved, shows polygonal vein islets with intruding branched veinlets.

The over-all shape and venation gives the appearance of *Vitis* but the looping of secondaries excludes it from that genus.

(Figured specimen bearing the number S 320 was collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta.)

(Pl. 38, fig. 242)

This is the only specimen of its kind in the collection. It is 80 mm long and 40 mm wide, elliptic, coarsely dentate. Major venation is pinnate, with about 10 pairs of secondaries, semi-craspedodromous. Minor venation is poorly preserved.

(Figured specimen bearing the number S 891 (B), was collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta.)

(Pl. 38, fig. 243)

This specimen is 48 mm long and 45 mm wide. Minor venation is poorly preserved. Major venation pattern and the coarse, gland-tipped, dentate, margin indicate affinity with the Vitaceae, not unlike that of *Ampelopsis*. It is quite possible that the specimen might represent an immature variant of *Ampelopsis acerifolia* (Newberry) Brown, described elsewhere in this thesis. However, the dentition of this

155.

Plate 38.

Figs. 240-243. Incertae sedis.

Fig. 240. (S 1073) X 1.2.

Fig. 241. (S 320) X 1.

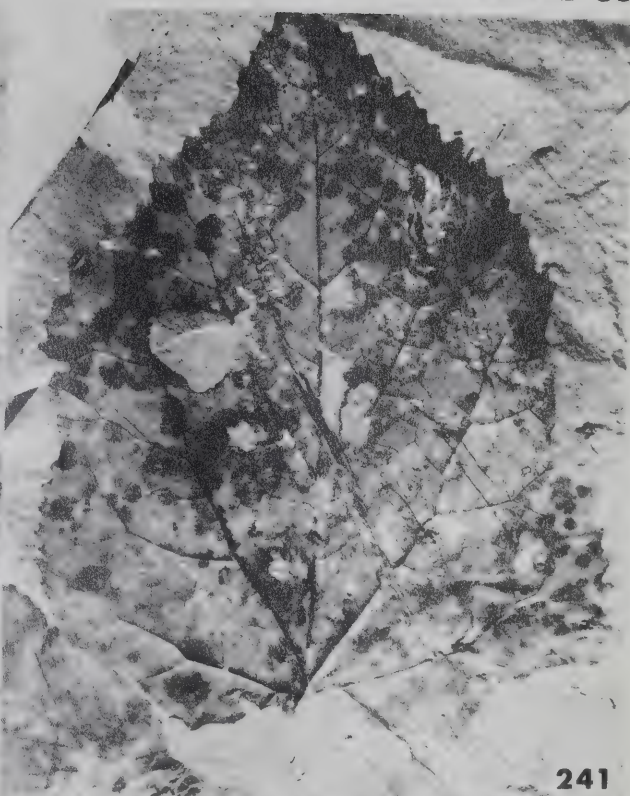
Fig. 242. (S 891 (B)) X 1.2.

Fig. 243. (S 1060) X 2.

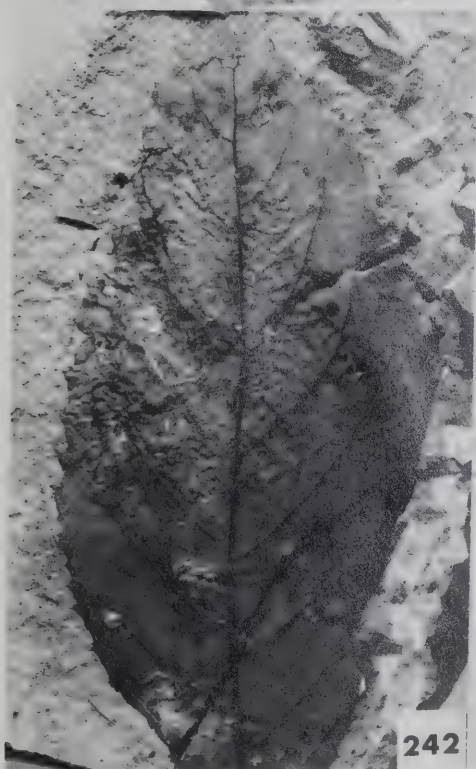
(Collected from Genesee, Alberta).



240



241



242



243

specimen and that of *Ampelopsis* is different. Hence it is not possible to treat them as congeneric with certainty.

(Figured specimen bearing the number S 1060 was collected from Genesee, Alberta and deposited in the paleobotanical collection, University of Alberta.)

CHAPTER 5

AGE OF THE FLORA

Several different approaches have been attempted in order to determine the age of the rocks containing the flora. For example samples of bentonitic clay were collected from the Genesee fossiliferous beds (text-fig. 2) but were found to be of no value for radiometric dating. Coal samples, collected from the various coal seams (text-fig. 2) were found to be poor in microfossils, which otherwise might have been useful for age determination. The stratigraphical position of the beds in relation to other outcrops of known age along the Red Deer River valley could not be determined precisely. Rutherford (1928) included the Genesee area in the Edmonton Formation.

The Edmonton Formation, assigned to an Upper Cretaceous age, is underlain by the marine Bearpaw Formation and overlain by the nonmarine Paskapoo Formation of Paleocene age (Bell, 1949). In general, the Edmonton is characterized by the presence of beds of bentonitic clay, carbonaceous shales, soft whitish sandstones and coal seams and the Paskapoo by the presence of massive, hard, light grey or yellowish brown weathered sandstone (Bell, 1949). The Edmonton beds are considered to be of Upper Cretaceous age by the presence of a known dinosaur fauna. There is also a difference of opinion with respect to the contact between Edmonton and Paskapoo Formations, i.e., whether they are conformable

representing a transitional Cretaceous-Tertiary boundary, or uncomformable (Bell, 1949; Irish, 1970).

The Edmonton Formation was subdivided variously by different investigators and an excellent summary is given by Irish (1970). He also made a stratigraphical revision of the Edmonton Formation raising it to a Group status. The Edmonton Group now comprises three Formations, the basal Horseshoe, the middle Whitemud and the upper Battle. The Paskapoo Formation was redefined (Irish, 1970) to include part of the Edmonton Formation in its original sense. Thus the Paskapoo Formation according to Irish (1970) now consists of strata of both Upper Cretaceous as well as Tertiary ages. The Upper Cretaceous strata are designated as the Scollard Member with the uppermost coal seam of the Ardley coal zone as its upper limit. A correlative of the Ardley coal seam known as the Coal Arch is exposed downstream about a mile from the Genesee fossil locality. The stratigraphic position of the sampled section illustrated in text-figure 2 with respect to the Coal Arch was indicated by Dr. R.S. Taylor (Spence Taylor and Associates Ltd., Edmonton). In his report he says, "If the sampled section was 30'+ above river level.....then the base of this section must lie at least 25' - and more probably 50' - above the top of the coal in the Coal Arch". In addition, on the basis of drill-hole logs he says, "I have no less than 130' of typical Edmonton Formation rocks above the Coal Arch zone in this general area. This is with no sign of disturbance in these rocks.

Thus, it appears reasonable to say that the base of your sampled section is no less than 80' below the top of the (lithologic) Edmonton Formation. It may well be significantly farther below the top of the Formation than this".

The foregoing information indicates that lithologically the fossiliferous beds at Genesee are of Upper Cretaceous age (Bell, 1949). It should, however, be noted that no dinosaur remains were found at the Genesee locality.

Age consideration based on the flora: Brayton (1953) in discussing the Lance age of the fossil flora of Genesee said that "Most of the identifiable species from Genesee flora have been reported from the Upper Cretaceous of North America" (p. 18); that, "the Pembina floral suite carries almost identical elements with those found in the Genesee floral suite. This would appear indicative that the Genesee floral suite was of latest Upper Cretaceous age" (Brayton, 1953, p. 19). The Pembina floral suite referred to is a list of species reported by Rutherford (1928, p. 23) which were originally determined by E.W. Berry. None of these species was made conspecific with the Genesee species in Brayton's description of the Genesee flora, except for *Populus arctica* Heer, which he synonymized with "*Trochodendroides arctica* Heer" (Brayton, 1953, p. 30); nor did he discuss in what ways he considered the "Pembina suite almost identical" (1953, p. 19) with the Genesee species.

In the present study of the Genesee fossil flora 18 elements have been identified of which 13 were identified to

the specific level. These are:

- Woodwardia arctica* (Heer) Brown
- Azolla schopfii* Dijkstra
- Glyptostrobus nordenskioldi* (Heer) Brown
- Metasequoia occidentalis* (Newberry) Chaney
- Taxodium dubium* (Sternberg) Heer
- Fokienia catenulata* (Bell) Brown
- Spirodela scutata* Dawson
- Cercidiphyllum genesevianum* sp. nov.
- C. flexuosum* (Hollick) n. comb.
- C. cuneatum* (Newberry) n. comb.
- Platanus raynoldsii* Newberry
- Tapiscia serrata* (Newberry) n. comb.
- Ampelopsis acerifolia* (Newberry) Brown.

Species from other formations which resemble the species listed above, were indicated and discussed under each species in chapter 4.

A comparison of the list of species with the type Lance flora (Dorf, 1942) shows that none of the species listed by Dorf as the "best indices of Lancian age" (p. 122) are present in the Genesee suite.

The information, in the discussion to follow on correlation, was gathered mostly from published descriptions and illustrations. Some of the original types were examined. Regarding published illustrations, as far as practicable, only photographs were consulted. For purposes of correlation species reported by Lesquereux (1878) in his "Tertiary Flora"

and Ward's (1887) "Types of the Laramie flora" were ignored. This is because of the doubts raised by Brown (1962, p. 4) with respect to the exact stratigraphical position of the species. In addition, species reported from formations whose precise stratigraphical positions are uncertain are also ignored for correlation.

Principles and assumptions relating to correlation and the difficulties experienced by investigators in delimiting taxa have become largely axiomatic and are excellently treated by Dorf (1942) and MacGinitie (1969). They are, therefore, not elaborated here.

Of the species identified in the Genesee fossil flora:

Metasequoia occidentalis (Newberry) Chaney, is too long-ranging (from Upper Cretaceous through Tertiary) to be useful for correlation.

Cercidiphyllum cuneatum (Newberry) n. comb. ranges from Upper Cretaceous (Berry, 1922) through late Eocene (Berry, 1926).

Cercidiphyllum genesevianum sp. nov. ranges from Upper Cretaceous (Lance) through lower Eocene if it is assumed that some of its variants are equivalent to *C. ellipticum* (Lance) and *C. elongatum* (Becker, 1960, Mormon Creek flora).

Cercidiphyllum flexuosum (Hollick) n. comb. ranges from Upper Cretaceous (Hollick, 1930) to Paleocene.

Ampelopsis acerifolia (Newberry) Brown, ranges from Upper Cretaceous (Bell, 1949) to Paleocene.

Taxodium dubium (Sternberg) Heer, ranges from Upper

Cretaceous to Paleocene.

The rest of the species with the exception of *Glyptostrobus nordenskioldi* (Heer) Brown are restricted elsewhere to beds of Paleocene age, viz., Raton, Fort Union, Denver of United States; Willow Creek (upper part), Paskapoo, post-Brazeau Paleocene, Paleocene (Mackenzie River Valley) and Alaska (Paleocene). *Glyptostrobus nordenskioldi* ranges from Paleocene to Eocene.

To summarize:

Long-ranging;

Metasequoia occidentalis (Newberry) Chaney

Upper Cretaceous to late Eocene;

Cercidiphyllum cuneatum (Newberry) n. comb.

Upper Cretaceous to lower Eocene;

Cercidiphyllum genesevianum sp. nov.

Upper Cretaceous to Paleocene;

Cercidiphyllum flexuosum (Hollick) n. comb.

Ampelopsis acerifolia (Newberry) Brown.

Taxodium dubium (Sternberg) Heer

Paleocene;

Woodwardia arctica (Heer) Brown

Azolla schopfi Dijkstra

Fokienia catenulata (Bell) Brown

Spirodela scutata Dawson

Platanus raynoldsii Newberry

Tapiscia serrata (Newberry) n. comb.

Paleocene to Eocene;

Glyptostrobus nordenskioldi (Heer) Brown

From the above analysis the Genesee flora is determined to be Paleocene in age. This conclusion based on the flora indicates that at least that portion of the Scollard Member of the Paskapoo Formation (Irish, 1970) including the Genesee fossil leaf beds is a part of the Paleocene and not the Upper Cretaceous as proposed by Irish (1970). Thus the Cretaceous-Tertiary boundary based on the evidence presented is somewhere below the Genesee fossil leaf beds.

CHAPTER 6.

FLORISTIC AND VEGETATIONAL ANALYSIS

Climatic consideration: Paleoclimates as inferred from plant megafossils are based on the assumption that the present is the key to the past. Such inferences are drawn in two different ways. First from the composition of the flora itself, i.e., from the species which comprise the assemblage and second, from study of the structural features of the plant remains. Results obtained from one method are used to corroborate the inferences drawn by the other method. Conclusions drawn from the assemblage of species are generally unreliable because they depend upon the accuracy of identification of those species. On the other hand, inferences obtained from the structural features of the leaves are independent of plant identification considerations and consequently are more reliable. In any event, one must exercise caution in utilizing these methods due to inherent limitations which govern a fossil assemblage. For example, the probability of an over representation of stream-side plants and lianas in a fossil assemblage is higher than for plants which grow even a few thousand feet away from a stream or lake (MacGinitie, 1969). It is also safe to assume that the majority of leaves which reach depositional sites belong to woody plants rather than herbs. In fact, leaves of herbaceous plants usually dry on the plants and never enter a depositional site. These comments are meant

to point out that foliar remains as indicators of climate give only a partial picture.

Floristic analysis: The interpretation of past climates based upon a comparison of a fossil flora with a modern one presupposes that the fossil flora thrived under similar climatic requirements as the modern one. The Genesee fossil flora comprising 18 elements, of which 13 were identified to the specific level, is a major *Metasequoia* - *Cercidiphyllum* association (nearly 80%) and is not a very good model for climatic interpretations, because of the small number of species. At best only broad inferences are possible.

The extant correlatives of some of the Genesee fossil species are as follows: Fossil species are on the left.

Glyptostrobus nordenskioldi (Heer) Brown = *G. pensilis* (Koch)

Metasequoia occidentalis (Newberry) Chaney = *M. glyptostro-*
boides Hu & Cheng.

Taxodium dubium (Sternberg) Heer = *Taxodium distichum* (L.)
Richards

Fokienia catenulata (Bell) Brown = *Fokienia* sp.

Cercidiphyllum spp. = *Cercidiphyllum* spp.

Platanus raynoldsii Newberry = *P. cuneata* Willd. (=oriental-
is)

Tapiscia serrata (Newberry) n. comb. = *T. sinensis* Oliv.

Ampelopsis acerifolia (Newberry) Brown = *Parthenocissus*
(*Ampelopsis*)
tricuspidata (Sieb.
& Zucc.) Planchon

With the exception of *Taxodium*, these are Asiatic species restricted mostly to China and Japan. In fact, *Metasequoia glyptostroboides*, *Cercidiphyllum japonicum sinicum* (=var. *sinense*) Rehd. and Wils. and *Tapiscia sinensis concolor* Cheng were reported living as ecological associates in Shu-hsa valley in the Hupeh province of eastern China (Chu and Cooper, 1950). Shui-hsa valley is located at approximately latitude 30° N and longitude 108° E, surrounded by mountains. The valley floor is humid with a constant temperature level. The altitude varies from 2000 to 4000 feet. The climate is warm temperate with a winter deficient and summer maximum precipitation and almost frostless winters. An analogous climatic situation probably existed at the Genesee locality with the only difference being that the species were living at a much lower altitude. That the climate was warm is also borne out by the presence of *Azolla*, which is essentially a tropical to warm temperate species.

Vegetational analysis: Analysis of structural features of fossil angiosperm leaves such as size, venation, texture, leaf tip and margin as related to environment have yielded significant results (Chaney and Sanborn, 1933; MacGinitie, 1941; Dorf, 1942; Dorf, 1969; Wolfe, 1969). The method is independent of the systematic relationships of the species and therefore the likelihood of error in interpretation, compared to floristic analysis, is minimized. The criteria for analysis have been developed from a study of

modern floras. Thus, for example, a coriaceous leaf texture is indicative of tropical environment, while a thin texture is associated with a temperate environment. Leaves of tropical rainforests are generally provided with an elongated drip tip. By far, the best indicator of environment appears to be the leaf margin, *viz.*, entire versus non-entire. Bailey and Sinnott (1916) have convincingly demonstrated a correlation between leaf margins and various climatic zones in the world. The details are not elaborated here, but suffice it to say that predominantly woody plants of tropical low lands possess an entire margin, while the predominantly woody plants in temperate regions possess a non-entire margin. As applied to fossil floras this is a quick and ready index to the prevailing climate. This criterion, when applied to the Genesee fossils, reveals that all the species of angiosperms with the exception of some entire-margined variants of *Cercidiphyllum cuneatum* (Newberry) n. comb. are non-entire margined indicating a warm temperate climate. But, strangely enough, nearly 40% of the leaves are of the "megaphyllous" class, i.e., more than 10 cm in length and over 2700 sq mm in area which is "indicative of lowland, tropical forests in regions of adequate rainfall throughout the year...." (Dorf, 1969). This apparent contradiction in the interpretation of climate, reflected by leaf margin versus leaf size, may be explained in terms of moderate to heavy precipitation. Such a precipitation distributed throughout the year,

coupled with a warmer climate, almost sub-tropical, might have been one of the guiding factors resulting in larger leaves. It is fully realized that production of large leaves is a result of a number of interacting environmental factors one such being optimum precipitation.

It is also interesting to note that a number of variants of *Cercidiphyllum genesevianum* sp. nov. in the Genesee flora show elongated tapering leaf tips (pl. 13, figs. 91, 95; pl. 14, fig. 96; pl. 18, fig. 123), probably drip tips (Dorf, 1969). Emphasizing this probability is necessary because a drip tip associated with a non-entire margin is also contradictory, since drip tip is known to be an adaptation usually associated with entire-margined leaves of species characteristic of tropical rainforests.

In addition to the structural features discussed above, which have been recognized to reflect the prevailing climate, Wolfe (1969, p. 36) states that the concentration of venation is yet another useful index. He points out that, "Tropical leaves have a pronounced tendency for the lamina to be supplied with many veins and this results in very small areoles; highly branching freely ending veinlets are less common than in temperate plants. As yet no quantification of this relationship has been made, involving as it does the clearing of leaves of all or most woody dicotyledonous species of floras in different climatic regimes. The relationship is, however, useful in determining the 'tropicality' or 'temperateness' of a given extinct

species or genus relative to extant related species and genera".

Although it is premature to assess fully the interesting observation of Wolfe (1969) it appears to have some bearing with respect to the Genesee fossil species of *Cercidiphyllum*. Thus, *C. genesevianum* sp. nov. and *C. cuneatum* (Newberry) n. comb., exhibit large vein islets with mean vein islet numbers of 1.8 and 1.9 respectively. They also show low mean veinlet termination numbers, i.e., 6 and 5 respectively indicating fewer freely branching veinlets per unit area, compared to modern *C. japonicum* with a mean veinlet termination number of 14. This apparent contradiction, i.e., larger vein islets and fewer veinlets, may be explained if we assume that the large vein islets coupled with fewer freely ending veinlets indicate climatic conditions which are warmer than warm temperate. The high degree of preservation of venation precludes the possibility that the low veinlet termination numbers might be due to poor preservation. As far as *C. flexuosum* (Hollick) n. comb. is concerned, a wide range of variation is seen, both in vein islet numbers as well as veinlet termination numbers (Table 17), which could not be interpreted in terms of climate.

Taking all factors into consideration, the Genesee assemblage indicates, a warm, humid temperate climate, with a winter 'dry' and summer 'wet' condition, comparable to a situation in the Shui-hsa valley in Hupeh, China. It may be

noted here, that ferns and a moss plant in the fossil assemblage also indicate a humid climate.

Local environmental conditions at the time of deposition:

In the absence of critical data on the lateral extent of the fossiliferous beds, nature of the facies, etc., it is hazardous to speculate on the environmental setting at the time of deposition. A look at text-figure 2 indicates that the deciduous angiosperm remains along with *Metasequoia* and other gymnosperm remains occur as a narrow band near the base of the section, giving way to *Azolla* slightly higher up. It has been pointed out in chapter 2 that the successive appearance of angiosperm remains and *Azolla* is gradational without any break. The only difference between these two 'zones' appears to be a change in the composition of sediments. The deciduous angiosperm remains occur in greyish compact shale, while the azollas occur in buff to grey shale with an irregular fracture. From this the original setting may be interpreted as follows:

The plants were growing around a very quiet body of water with poor drainage fed by streams in which the water flow was very slow, as borne out by the fine-grained sediments. The leaf compressions preserved flat in fine-grained shale with excellent preservation indicate very little transport. The presence of *Glyptostrobus* and *Taxodium* point to a swampy, stagnant situation. *Cercidiphyllum* and *Metasequoia* along with the vitaceous members (lianas) represent stream-side vegetation not very far from

the site. In this context, MacGinitie records that *Cercidiphyllum* "is a common stream-side type and thrives in moist, rich soils" (1941, p. 38); Chu and Cooper record that *Metasequoia* thrives "along the banks of streams, among rocks and boulders covered thickly by liverworts and mosses....." (1950, p. 270). At some point of time, the stream appears to have been blocked and *Azolla* and *Spirodela* seem to have been introduced along with a change in regimen of the sediments. This may partially explain why the deciduous angiosperms never re-appeared immediately after the azollas were deposited. The remarkable preservation of reproductive structures *in situ* on azolla plants, seems to indicate that they have not undergone transport but formed part of the floating vegetation in the basin. Another view which could explain the disappearance of dry ground angiosperms and *Metasequoia* by the time *Azolla* was introduced is that inundation of the area took place. A large scale inundation would eliminate *Cercidiphyllum* and *Metasequoia* which have not been shown to develop pneumatophores for survival in a stagnant habitat. Both views are tenable and at the same time speculative in the absence of a clear idea about the rates of sedimentation which might reflect the time involved and account for the 'succession' of species in the fossil beds.

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GLOSSARY

The terms and their explanations have been drawn from various sources (Kerner and Oliver, 1902; Levin, 1929; Hall and Melville, 1951; Lawrence, 1968; Hickey, 197-). Some terms have been modified from their sources and a few others are new.

Acicular: Needle-shaped.

Acropetiolar: At the junction of midrib and petiole.

Acuminate: Acute apex with somewhat concave sides tapering to a protracted point.

Acute: Sharp apex ending in a point, the sides of apex straight or convex.

Arcuate: Curved or bowed.

Attenuate: Elongate apex tapering gradually.

Basal: Arising from a single point at the base.

Camptodromous: Primary or secondary veins not reaching margin of leaf.

Chartaceous: Of papery texture.

Coriaceous: Of thick texture.

Craspedodromous: Primary or secondary veins terminating at the margin of leaf.

Craspedo-camptodromous: Secondary vein proceeding towards margin of leaf, curving upwards to join the super-adjacent secondary forming a loop.

Cuneate: Wedge-shaped with straight sides.

Decurrent: Leaf base extending down to a very short distance along the petiole.

Dentate: Sharp, coarse teeth perpendicular to the margin of leaf.

Divergent: Primary veins proceeding away from the midrib.

Elliptic: Oval shape with rounded narrow ends and widest at or about the middle.

Emergent: Glands projecting out from the margin of leaf.

Finely crenate: Crenate teeth with very narrow angular sinuses.

Glandular-entire: Entire margin with glands on the margin of leaf.

Mucro: A short and sharp abrupt spur or spiny tip.

Non-emergent: Glands not projecting out from the margin of leaf.

Obovate: Tertiary veins connecting secondaries, curving abaxially from midrib.

Outer Secondary vein: Secondary vein arising from a primary abaxially.

Ovate: Oval shape with widest portion below the middle.

Peltate: Attachment of petiole inside the margin of leaf.

Primary vein: Vein flanking midrib having a point of origin in common with the midrib.

Retuse: Obtuse apex notched slightly.

Rounded obtuse: Blunt rounded leaf base with an angle less than 180° .

Semi-craspedodromous: Secondary vein branching at the margin

of the leaf, one of the branches terminating at the margin and the other joining the superadjacent secondary.

Sinus: Space or recess between two successive teeth.

Strong secondary vein: First distal secondary from the midrib thicker than the subjacent weaker secondaries.

Suprabasal: Point of origin of primary veins 2 or 3 mm above the point of origin of midrib.

Truncate: Leaf base, 180° .

Undulate-glandular: Glandular, toothed margin, teeth with very wide shallow sinuses; glands apical on teeth.

Vein islet: Ultimate unit of the reticulate vein meshwork of leaf enclosing freely-ending veinlet or veinlets; of variable shape and area.

Veinlet termination: Unbranched or branched ultimate veinlet ending freely inside a vein islet.

Weak secondary vein: Secondary vein arising from the midrib subjacent to the strong secondaries.

Zig zag: Veins making abrupt, sharp, alternate right and left turns in their course.

APPENDIX

1. Width is measured at the widest part of the lamina.
2. Length and width are recorded in millimeters; area in square millimeters.
3. Area is an approximate calculation obtained by the formula length x width x $2/3$ (Dorf, 1969).
4. P.A. - Primary angle; the angle between the inner primaries flanking the midrib.
5. W.S. - Weak secondary angle; the adaxial angle between the weak secondaries and the midrib measured on either side of the midrib at the widest portion of the lamina; the angle represents the mean of 3 or 4 measurements.
6. S.S. - Strong secondary angle; the adaxial angle between the first strong distal secondaries arising from the midrib and the midrib; the angle is a mean of the first two successive strong secondaries on either side of the midrib.
7. O.S. - Outer secondary angle; the adaxial angle between the successive, proximal outer secondaries arising from the inner primaries and the inner primaries on either side of the midrib; the angle represents a mean of 3 or 4 measurements.
8. L/W - the ratio between length and width.
9. V.I. #. - Vein islet number; number of vein islets per square millimeter measured at random between midrib and the margin at the widest portion of the lamina; the

figure represents a mean of 16 measurements in living material; variable in fossils depending on preservation.

10. V.T. #. - Veinlet termination number; number of freely ending veinlet terminations per square millimeter; measurement same as in V.I. #.
11. (Dist.) - Distorted leaf.
12. (Lo) - Lower surface of specimen.
13. (P) - Peel.
14. Sp.# - Specimen number.

TABLE 1. *Cercidiphyllum japonicum* Sieb. and Zucc.

(Short shoot).

<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
504	26	28	180	85	67	65	55	0.9
682	33	31	180	60	70	50	50	1.1
840	36	35	180	70	70	65	50	1.0
1032	37	43	180	80	73	70	50	0.9
1056	37	44	180	80	67	70	55	0.8
1066	41	39	180	70	65	60	55	1.0
1148	43	41	180	90	62	57	57	1.0
1288	46	42	180	50	60	55	50	1.1
1320	44	44	180	65	70	60	55	1.0
1380	46	45	180	60	60	60	50	1.0
1408	44	47	180	80	75	70	50	0.9
1472	47	46	180	60	65	55	50	1.0
1530	51	45	180	60	60	65	50	1.1
1664	48	52	180	70	65	60	50	0.9
1680	46	56	180	80	65	75	60	0.8
1800	54	50	180	60	75	60	50	1.1
1976	56	52	180	60	57	70	50	1.1
2120	59	53	180	55	65	67	50	1.1
2242	58	59	180	55	65	57	50	1.0
2552	58	66	180	70	65	60	50	0.9
1120	35	48	180	75	70	60	60	0.7
1344	42	68	180	60	70	60	55	0.9
1350	45	45	180	60	75	60	50	1.0
1470	49	46	180	60	70	55	50	1.1
1470	46	49	180	60	65	55	50	0.9
1656	46	54	180	70	70	60	50	0.9
1664	52	48	180	60	70	55	40	1.1
1728	48	54	180	70	70	55	60	0.9
1908	54	53	180	60	65	55	50	1.0
2014	57	53	180	50	70	50	55	1.1
572	26	33	180	85	65	55	50	0.8
666	28	37	180	80	65	60	50	0.7

TABLE 1. Cont'd.

<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
884	34	38	180	90	65	65	50	0.9
910	35	39	180	80	65	65	50	0.9
962	37	39	180	70	70	55	50	0.9
984	35	41	180	80	60	60	50	0.8
1064	38	42	180	75	70	55	50	0.9
1118	40	43	180	80	70	55	60	0.9
1118	40	43	180	75	65	55	55	0.9
1140	38	45	180	80	70	60	55	0.8
1140	38	45	180	80	70	60	55	0.8
1316	42	47	180	70	70	60	55	0.9
1536	48	48	180	65	65	55	50	1.0
1568	48	49	180	60	65	60	50	1.0
1590	44	53	180	100	65	55	50	0.8
1066	39	41	180	60	65	55	50	0.9
1120	40	42	180	60	65	60	60	0.9
1140	45	38	180	50	65	60	50	1.2
1288	46	42	180	45	60	50	50	1.1
1408	48	44	180	60	65	55	50	1.1
2310	64	55	180	45	70	60	50	1.2
2320	61	58	180	70	70	60	50	1.0
2240	59	56	180	70	65	55	55	1.0
2394	63	57	180	60	60	65	50	1.1
2990	69	65	180	70	65	65	55	1.0
1144	44	39	180	60	65	60	50	1.1
1290	43	45	180	70	70	60	55	0.9
1320	44	44	180	60	60	60	50	1.0
1504	47	48	180	60	65	55	55	1.0
1600	48	50	180	60	65	60	55	1.0
2244	66	51	180	60	65	60	50	1.3
2604	62	63	180	70	70	60	55	1.0
2990	68	65	180	70	65	65	65	1.0

TABLE 1. Cont'd.

<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
3588	78	69	180	60	70	70	60	1.1
4500	90	75	180	55	70	65	55	1.2
836	33	38	180	90	70	60	50	0.9
1144	40	44	180	80	70	60	50	0.9
1316	41	47	180	80	70	50	50	0.9
1696	53	43	180	50	65	50	50	1.1
1760	55	47	180	45	65	60	55	1.1
1944	54	54	180	70	70	60	60	1.0
2014	53	58	180	80	70	60	50	0.9
2352	63	56	180	50	65	50	55	1.1
2470	65	56	180	55	65	65	50	1.1
2720	68	60	180	60	70	60	50	1.1

TABLE 2. *Cercidiphyllum japonicum* Sieb. and Zucc. (Short shoot leaves)
 Total number of specimens: 120

Ranges:

Smallest: Length 26 mm. Width 28 mm. Area 504 sq. mm.

Largest: Length 90 mm. Width 75 mm. Area 4500 sq. mm.

P.A. 45-100; W.S. 40-75; O.S. 50-75; S.S. 40-65; L/W 0.7-1.3; V.I.# 0.4-2.8; V.T.# 7-27.

Number of specimens studied for analysis: 75

P.A.	Mean: 70	W.S.	Mean: 67	O.S.	Mean: 59	S.S.	Mean: 52	L/W	Mean: 1.0
P.A.	<u>Freq.</u>	<u>W.S.</u>	<u>Freq.</u>	<u>O.S.</u>	<u>Freq.</u>	<u>S.S.</u>	<u>Freq.</u>	<u>L/W</u>	<u>Freq.</u>
45	3	55	1	50	6	40	1	0.7	2
50	5	60	7	55	18	50	46	0.8	7
55	4	62	1	57	2	55	19	0.9	23
60	24	65	32	60	32	57	1	1.0	20
65	2	67	2	65	10	60	7	1.1	19
70	15	70	28	67	1	65	1	1.2	3
75	3	73	1	70	5			1.3	1
80	13	75	3	75	1				
85	2								
90	3								
100	1								

TABLE 3. *Cercidiphyllum japonicum* Sieb. and Zucc.

(Long and sucker shoots)

<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
440	34	20	100	60	70	70	60	1.7
504	35	21	100	60	75	62	60	1.7
600	36	25	100	60	70	67	45	1.4
760	38	30	140	70	70	75	50	1.3
868	42	31	120	65	70	60	60	1.4
880	44	30	140	60	60	55	50	1.5
946	43	33	175	75	65	66	55	1.3
968	44	34	110	70	70	70	60	1.3
1152	48	36	140	70	67	73	65	1.3
1280	48	40	155	60	70	55	45	1.2
1368	54	38	170	75	77	75	60	1.3
1484	53	41	180	70	80	60	50	1.3
2200	65	50	180	70	77	65	65	1.3
2200	66	50	180	85	80	65	60	1.3
448	32	21	105	40	60	62	55	1.5
624	35	26	175	70	77	65	60	1.3
666	37	26	120	60	65	60	50	1.4
728	41	26	155	60	85	65	65	1.6
748	34	32	160	70	65	65	50	1.0
780	44	26	130	60	78	70	70	1.7
800	40	30	180	70	82	62	55	1.3
812	43	29	140	50	80	65	50	1.5
820	41	30	150	60	70	75	50	1.4
880	44	29	145	55	75	70	55	1.5
882	49	28	120	60	80	70	60	1.7
896	43	32	140	65	75	60	60	1.3
1000	50	30	150	55	75	65	67	1.7
1024	48	32	160	60	80	65	65	1.5
1050	45	35	120	50	70	60	65	1.3
1056	44	36	180	75	85	67	65	1.2
1078	49	34	150	60	82	70	60	1.4

TABLE 3. Cont'd.

<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
1088	47	34	170	60	75	67	60	1.3
1104	46	37	175	60	72	70	65	1.2
1104	46	37	140	60	87	62	60	1.3
1156	51	34	175	60	75	70	60	1.5
1170	45	39	170	70	80	75	55	1.1
1200	50	37	140	55	77	60	60	1.3
1248	52	36	175	65	85	70	60	1.4
1260	54	35	170	65	75	70	60	1.5
1274	49	38	120	50	70	75	60	1.3
1274	49	38	120	55	65	60	60	1.3
1274	49	38	120	50	65	52	50	1.3
1300	50	39	180	65	72	65	60	1.3
1312	48	41	160	60	68	70	55	1.2
1404	54	39	140	55	77	62	60	1.4
1440	54	40	180	70	80	65	60	1.3
1444	57	38	175	60	77	75	60	1.5
1496	50	44	145	60	82	65	60	1.1
1500	50	45	140	60	75	65	60	1.1
1590	53	45	180	60	80	75	55	1.2
1650	55	44	175	70	75	70	65	1.3
1680	56	46	180	75	85	75	60	1.2
1740	58	46	180	70	80	65	65	1.3
1862	58	49	170	60	87	70	60	1.2
2108	62	50	165	65	80	65	60	1.2
1404	54	39	180	100	85	75	70	1.4
1806	63	43	180	80	72	70	65	1.5
2142	63	51	180	105	85	70	70	1.2
2420	66	55	180	100	85	75	65	1.2
2720	68	60	180	100	80	73	75	1.1
2960	74	60	180	80	80	70	70	1.2
3040	80	56	180	100	85	75	65	1.4
3192	76	64	180	100	83	67	65	1.2

TABLE 3. Cont'd.

<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
3608	82	65	180	80	85	70	60	1.3
4088	85	73	180	90	85	73	65	1.2
1050	45	35	180	85	80	75	65	1.3
1394	51	41	180	90	80	77	65	1.2
1248	52	37	180	80	87	67	60	1.4
1440	48	45	180	80	88	75	65	1.0
1600	60	40	180	75	75	67	65	1.5
2200	66	50	180	75	72	65	50	1.3
2592	72	54	180	105	90	75	65	1.3
2668	69	58	180	100	85	75	70	1.2
4128	86	73	180	85	85	70	60	1.2
4350	87	76	180	80	75	62	60	1.1

TABLE 4. *Cercidiphyllum japonicum* Sieb. and Zucc. (Long and sucker shoot leaves)

Total number of specimens: 145

Ranges:

Smallest: Length 34 mm. Width 20 mm. Area 440 sq. mm.

Largest: Length 87 mm. Width 76 mm. Area 4350 sq. mm.

P.A. 40-105; W.S. 55-90; O.S. 40-90; S.S. 45-75; L/W 1.0-1.7; V.I.# 0.4-1.9; V.T.# 6-27.

Number of specimens studies for analysis: 75

P.A.	Mean: 70	W.S.	Mean: 77	O.S.	Mean: 68	S.S.	Mean: 60	L/W	Mean: 1.3
P.A.	Freq.	W.S.	Freq.	O.S.	Freq.	S.S.	Freq.	L/W	Freq.
40	1	60	2	52	1	45	2	1.0	2
50	4	65	5	55	2	50	9	1.1	5
55	5	67	1	60	7	55	7	1.2	16
60	22	68	1	62	6	60	31	1.3	26
65	6	70	9	65	15	65	19	1.4	10
70	12	72	4	66	1	67	1	1.5	10
75	6	75	11	67	6	70	5	1.6	1
80	6	77	6	70	18	75	1	1.7	5
85	3	78	1	73	3				
90	2	80	14	75	15				
100	6	82	3	77	1				
105	2	83	1						
		85	12						
		87	3						
		88	1						
		90	1						

TABLE 5. *Cercidiphyllum magnificum* (Nakai) Nakai

(Short shoot)

<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
896	32	42	180	90	70	55	50	0.8
1170	39	45	180	80	70	55	50	0.9
1204	43	42	180	80	60	50	60	1.0
1320	45	44	180	90	60	55	50	1.0
1500	45	50	180	85	70	60	50	0.9
1504	48	47	180	80	60	60	50	1.0
1600	48	50	180	80	70	55	50	1.0
1692	47	54	180	90	65	55	50	0.9
1836	54	51	180	70	70	50	50	1.0
1972	51	58	180	85	70	60	50	0.9
1972	58	51	180	60	70	55	50	1.1
1976	57	52	180	60	70	60	40	1.1
2006	51	59	180	85	70	55	50	0.9
2432	64	57	180	60	70	55	50	1.1
2480	60	62	180	80	70	60	60	1.0
2760	69	60	180	80	70	60	50	1.1
2806	69	61	180	70	70	60	50	1.1
2940	70	63	180	60	70	55	50	1.1
2940	63	70	180	80	60	65	50	0.9
2948	67	66	180	80	72	60	50	1.0
3168	66	72	180	75	70	60	45	0.9
3216	67	72	180	80	70	62	55	0.9
3220	69	70	180	70	80	55	40	1.0
3264	72	68	180	70	70	60	50	1.0
3500	75	70	180	75	75	60	45	1.1
3500	70	75	180	70	70	55	50	0.9
3500	75	70	180	70	70	60	50	1.1
3542	77	69	180	60	70	60	50	1.1
3550	71	75	180	70	65	55	55	0.9
3942	73	81	180	75	70	60	50	0.9
4000	75	80	180	80	70	60	50	0.9
4100	75	82	180	80	70	65	50	0.9

TABLE 5. Cont'd.

<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
4104	76	81	180	80	70	60	50	0.9
4160	78	80	180	60	80	60	50	1.0
4212	81	78	180	70	70	50	50	1.0
4312	77	84	180	70	68	45	45	0.9
4480	84	80	180	60	75	60	50	1.0
4536	84	81	180	70	75	60	55	1.0
4984	84	89	180	75	60	50	50	0.9
5700	95	90	180	70	65	65	55	1.0

TABLE 6. *Cercidiphyllum magnificum* (Nakai) Nakai (Short shoot leaves)

Number of specimens studied for analysis: 40

Ranges:

Smallest: Length 32 mm. Width 42 mm. Area 896 sq. mm.

Largest: Length 95 mm. Width 90 mm. Area 5700 sq. mm.

P.A. 60-75; W.S. 60-80; O.S. 45-65; S.S. 40-60; L/W 0.8-1.1; V.I.# 0.8-2.0; V.T.# 5-15

P.A.	Mean: 75	W.S.	Mean: 69	O.S.	Mean: 57	S.S.	Mean: 50	L/W	Mean: 1.0
<u>P.A.</u>	<u>Freq.</u>	<u>W.S.</u>	<u>Freq.</u>	<u>O.S.</u>	<u>Freq.</u>	<u>S.S.</u>	<u>Freq.</u>	<u>L/W</u>	<u>Freq.</u>
60	7	60	5	45	1	40	2	0.8	1
70	11	65	3	50	4	45	3	0.9	16
75	4	68	1	55	12	50	29	1.0	14
80	12	70	25	60	19	55	4	1.1	9
85	3	72	1	62	1	60	2		
90	3	75	3	65	3				
		80	2						

TABLE 7. *Cercidiphyllum magnificum* (Nakai) Nakai

(Long shoot)

<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
288	27	16	180	60	70	60	50	1.7
336	28	18	180	60	65	60	50	1.5
360	27	20	180	60	60	55	45	1.3
414	27	23	180	55	60	55	45	1.2
500	30	25	180	60	70	50	50	1.2
736	46	24	180	60	75	50	55	2.0
740	37	30	180	50	60	55	50	1.2
760	38	30	180	70	60	55	50	1.3
792	44	27	180	60	70	55	50	1.6
800	40	30	180	50	65	55	50	1.3
840	35	36	180	60	70	55	45	1.0
900	45	30	180	75	65	55	50	1.5
920	46	30	180	80	65	50	50	1.5
962	39	37	180	60	60	50	50	1.0
984	41	36	180	60	70	50	50	1.1
984	41	36	180	70	60	55	50	1.1
1024	48	32	180	60	60	50	50	1.5
1056	48	33	180	60	60	55	50	1.4
1110	45	37	180	70	60	55	50	1.5
1120	42	40	180	60	60	50	55	1.0
1156	51	34	180	70	65	55	50	1.5
1200	45	40	180	60	70	50	40	1.1
1216	48	38	180	60	65	50	45	1.3
1230	45	41	180	70	70	55	50	1.1
1278	46	42	180	50	60	50	40	1.1
1408	48	44	180	65	70	55	45	1.1
1428	51	42	180	70	65	50	45	1.2
1470	49	45	180	60	75	60	55	1.1
1560	52	45	180	60	65	55	50	1.1
1638	63	39	180	60	60	60	50	1.6
1720	60	43	180	60	60	55	50	1.4
1824	57	48	180	70	75	60	55	1.2

TABLE 7. Cont'd.

<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
1856	58	48	180	70	65	65	50	1.2
2006	59	51	180	60	70	55	55	1.1
2160	60	54	180	70	70	60	50	1.1
2196	61	54	180	60	65	55	50	1.1
2200	60	55	180	60	70	60	55	1.1
2312	68	51	180	60	70	50	55	1.3
2376	66	54	180	60	70	55	50	1.2
2546	67	57	180	75	70	55	55	1.2

TABLE 8. *Cercidiphyllum magnificum* (Nakai) Nakai (Long shoot leaves)

Number of specimens studied for analysis: 40

Ranges:

Smallest: Length 27 mm. Width 16 mm. Area 288 sq. mm.

Largest: Length 67 mm. Width 57 mm. Area 2546 sq. mm.

P.A. 50-80; W.S. 60-75; O.S. 50-65; S.S. 40-55; L/W 1.0-2.0; V.I.# 1.2-5.5; V.T.# 7-30

P.A. Mean: 63 W.S. Mean: 66 O.S. Mean: 55 S.S. Mean: 50 L/W Mean: 1.3

P.A.	Freq.	W.S.	Freq.	O.S.	Freq.	S.S.	Freq.	L/W	Freq.
50	3	60	13	50	12	40	2	1.0	3
55	1	65	10	55	20	45	6	1.1	12
60	23	70	14	60	7	50	24	1.2	8
65	1	75	13	65	1	55	8	1.3	5
70	9							1.4	2
75	2							1.5	6
80	1							1.6	2
								1.7	1
								2.0	1

TABLE 9. *Cercidiphyllum japonicum* Sieb. and Zucc..

Data from cleared slides

<u>Slide #</u>	<u>Area</u>	<u>V.I.#</u>	<u>V.T.#</u>	<u>Type of leaf</u>	<u>Locality</u>
50	130	1.1	9	Short shoot	Nagano prefecture, Japan.
48	160	0.5	8	"	
46	226	1.0	9	"	
12	226	2.8	27	"	
26	430	0.9	13	"	
21	612	1.2	13	"	
25	672	0.7	9	"	
20	740	0.8	10	"	
30	792	0.7	14	"	
29	906	0.6	10	"	
22	984	0.7	11	"	
49	1008	0.3	11	"	
47	1066	0.5	8	"	
24	1184	0.6	10	"	
51	1216	0.7	9	"	
23	1540	0.6	14	"	
43	164	1.3	6	Long shoot	"
17	210	1.9	21	"	"
45	230	1.9	16	"	"
14	306	1.6	16	"	"
15	386	0.9	15	"	"
44	470	0.8	8	"	"
13	498	0.9	8	"	"
28	594	0.9	11	"	"
32	606	0.8	9	"	"
19	826	0.5	9	"	"
18	848	0.4	13	"	"
27	896	0.6	9	"	"
11	360	1.7	20	Short shoot	Koishikawa, Japan.
8	600	0.8	24	"	
10	612	1.1	16	"	

Table 9. Continued.

<u>Slide #</u>	<u>Area</u>	<u>V.I.#</u>	<u>V.T.#</u>	<u>Type of leaf</u>	<u>Locality</u>
9	1040	0.8	10	Short shoot	Koishikawa, Japan.
2	246	1.4	21	Long shoot	"
1	774	1.2	27	"	"
38	638	0.7	11	Short shoot	New York Botanic Garden
36	886	0.4	13	"	
31	984	1.1	13	"	"
5	1038	1.0	14	"	"
34	1230	0.5	7	"	"
37	522	0.4	16	Sucker shoot	"
4	576	0.4	8	"	"
3	680	0.4	11	"	"
35	884	0.6	15	"	"
33	1086	0.7	24	"	"
39	814	0.7	13	Short shoot	Arnold Arboretum
41	1090	0.9	9	"	
7	230	1.0	18	Long shoot	
6	360	1.5	19	"	
40	838	0.7	21	Sucker shoot	
42	1284	0.9	23	"	

TABLE 10. *Cercidiphyllum magnificum* (Nakai) Nakai. Data from cleared slides.

<u>Slide #</u>	<u>L</u>	<u>W</u>	<u>Area</u>	<u>V.I.#</u>	<u>V.T.#</u>	<u>Locality and remarks</u>	
56	27	34	612	0.8	5	Japan	Short shoot leaf
58	30	40	800	1.4	7	"	"
59	38	39	988	2.0	15	"	"
--	80	78	4160	1.5	6	"	"
--	82	78	4264	0.8	6	"	"
55	19	9	114	5.0	16	"	Long shoot leaf
60	20	12	160	5.5	30	"	"
53	30	22	440	3.5	26	"	"
61	30	22	440	2.2	17	"	"
54	30	27	540	2.4	17	"	"
57	35	25	584	1.2	11	"	"
--	42	36	1008	2.2	16	"	"
--	60	56	2240	1.5	7	"	"
--	60	57	2280	1.6	7	"	"

TABLE 11.

<u>Species</u>	<u>Mean V.I.#</u>	<u>Mean V.T.#</u>
<i>Cercidiphyllum japonicum</i>	0.8	13.6
<i>Cercidiphyllum magnificum</i>	2.4	13.3

TABLE 12. *Cercidiphyllum genesevianum* sp. nov.

<u>Sp. #</u>	<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
1075	234	22	16	140	60	70	55	65	1.4
299	246	23	16	160	60	70	80	--	1.4
1064	290	29	15	130	60	60	60	60	2.0
1324(B)	322	23	21	110	60	57	60	--	1.0
287(Lo)	418	33	19	145	60	55	55	60	1.7
358(B)	454	31	22	130	60	70	65	--	1.4
364/363	656	41	24	120	60	65	65	65	1.7
307	760	38	30	130	60	60	60	--	1.3
200/164	968	44	33	160	65	65	80	75	1.3
1088	1000	50	30	160	60	60	60	60	1.7
2824	1012	46	33	155	60	62	62	--	1.4
871	1024	48	32	140	80	80	75	60	1.5
1035	1344	48	42	140	70	70	65	70	1.1
2821	400	30	20	180	65	58	65	45	1.5
1020	560	29	29	180	80	75	70	60	1.0
1316	592	37	24	180	70	85	82	60	1.5
325	616	33	28	180	90	86	80	70	1.2
1058(A&B)	672	42	24	180	60	60	55	--	1.8
1596(A&B)	716	43	25	180	80	60	75	60	1.7
1046	740	37	30	180	70	75	70	60	1.2
938(A&B)	750	45	25	180	60	82	78	65	1.8
773/763	846	47	27	180	70	60	70	50	1.7
287(Lo)	902	41	33	180	70	75	87	65	1.2
242	920	46	30	180	70	75	80	--	1.5
355(Lo)	952	42	34	180	60	75	70	--	1.2
365	952	42	34	180	60	75	75	60	1.2
345	1032	43	36	180	70	75	70	70	1.2
1586(A)	1044	54	29	180	70	65	75	--	1.9
300	1060	43	37	180	100	80	80	--	1.1
1338(A&B)	1078	49	33	180	70	75	80	65	1.5
1024(B)	1088	48	34	180	65	85	87	65	1.4

TABLE 12. Continued.

<u>Sp. #</u>	<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
1327	1100	50	33	180	60	65	70	60	1.5
1601	1110	45	37	180	60	80	70	--	1.2
381	1176	49	36	180	60	85	75	--	1.3
229	1216	48	38	180	80	75	87	65	1.3
932	1288	46	42	180	90	75	70	--	1.1
287	1316	47	42	180	80	90	90	60	1.1
769	1470	63	35	180	70	70	75	--	1.8
182/186 (Lo)	1520	60	38	180	80	87	80	--	1.6
927 (B)	1540	55	42	180	70	65	70	50	1.3
927 (B)	1586	61	39	180	60	87	70	50	1.5
268	1628	66	37	180	65	85	75	70	1.8
767 (Lo)	1672	66	38	180	60	62	65	--	1.8
2843	1672	57	44	180	95	80	80	--	1.3
947	1680	63	40	180	80	85	75	60	1.6
392	--	--	41	180	60	87	80	65	--
382	1736	62	42	180	60	77	77	65	1.5
334/335	--	--	43	180	70	85	80	65	--
1034	1920	60	48	180	70	65	65	55	1.3
883 (A&B)	1976	57	52	180	60	60	60	50	1.1
1047	2108	62	51	180	60	65	65	--	1.2
372/373	2124	59	54	180	60	75	70	--	1.0
340/346	2312	68	51	180	60	60	57	--	1.3
409 (A&B)	2318	61	57	180	60	60	50	65	1.1
867/817	2332	66	53	180	60	60	70	65	1.3
1317	2394	63	57	180	55	55	50	60	1.1
837/828	2450	75	49	180	60	62	60	50	1.5
1022 (A)	2816	65	65	180	70	65	60	60	1.0
1597	3000	75	60	180	50	60	50	50	1.3
2819 (A)	3024	81	56	180	50	60	60	--	1.4
776	3036	69	66	180	70	65	55	--	1.0
1016 (A)	3136	84	56	180	50	80	68	--	1.5
251	3150	75	63	180	75	70	70	--	1.2
1607 (A&B)	3200	80	60	180	80	75	85	60	1.2

TABLE 12. Continued.

<u>Sp.#</u>	<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
1024 (B)	3256	74	66	180	80	82	87	70	1.2
171	3276	78	63	180	75	65	70	65	1.2
896	3402	81	63	180	105	87	87	--	1.3
258 (A)	3520	80	66	180	60	63	60	--	1.2
924	3796	78	73	180	70	75	72	--	1.0
1586 (A&B)	3850	77	75	180	80	75	66	--	1.0
1594	4000	100	60	180	60	87	80	--	1.7
389		--	66	180	65	87	77	--	--
997	4672	102	69	180	85	88	80	--	1.5
1074	4888	94	78	180	60	87	78	--	1.2
987 (A)	--	--	54	180	70	65	65	--	--

TABLE 13. *Cercidiphyllum genesevianum* sp. nov.

Sp. #	Area	L	W	Base	P.A.	W.S.	O.S.	S.S.	L/W	V.I.#	V.T.#
1064	290	29	15	130	60	60	60	60	2.0	3	--
287(Lo)	418	33	19	145	60	55	55	60	1.7	4	--
364/363	656	41	24	120	60	65	65	65	1.7	6.5	6
1088	1000	50	30	160	60	60	60	60	1.7	3.5	6
1035	1344	48	42	140	70	70	65	70	1.1	3.5	5
1020	560	29	29	180	80	75	70	60	1.0	1.5	--
1316	592	37	24	180	70	85	82	60	1.5	2	6
325	616	33	28	180	90	86	80	70	1.2	2	--
1596(A&B)	716	43	25	180	80	60	75	60	1.7	1.2	6
773/763	846	47	27	180	70	60	70	50	1.7	2	4
345	1032	43	36	180	70	75	70	70	1.2	1.5	4
1601	1110	45	37	180	60	80	70	--	1.2	1.3	--
381	1176	49	36	180	60	85	75	--	1.3	1.3	--
229	1216	48	38	180	80	75	87	65	1.3	1.3	4
1612(A&B)	1520	57	40	180	80	77	70	60	1.4	1.5	7
268	1628	66	37	180	65	85	75	70	1.8	2	7
342(Lo)	1680	60	42	180	60	67	80	60	1.4	2.5	6
947	1680	63	40	180	80	85	75	60	1.6	1	4
392	1722	63	41	180	60	87	80	65	1.5	1	--
985	1892	66	43	180	70	65	70	--	1.5	2.2	--
1034	1920	60	48	180	70	65	65	55	1.3	2.7	--

TABLE 13. Cont'd.

Sp. #	Area	L	W	Base	P.A.	W.S.	O.S.	S.S.	L/W	V.I.#	V.T.#
1557(Dist.)	2240	70	48	180	--	--	--	--	1.4	0.7	--
409(A&B)	2318	61	57	180	60	60	50	65	1.1	1.5	6
837/828	2450	75	49	180	60	62	60	50	1.5	1	--
1022(A)	2816	65	65	180	70	65	60	50	1.0	1	--
1597	3000	75	60	180	50	60	56	50	1.3	0.8	--
2819(A)	3024	81	56	180	50	60	60	--	1.4	4	--
776	3036	69	66	180	70	65	55	--	1.0	1	4
251	3150	75	63	180	70	70	70	--	1.2	0.8	4
1024(B)	3256	74	66	180	80	82	87	70	1.2	1.0	6
171	3276	78	63	180	75	65	70	65	1.2	1.0	--
1078(B)	3652	83	66	180	90	80	85	--	1.2	1	--
924(Dist.)	3796	78	73	180	70	75	72	--	1.0	2.5	8
1586(A&B)	3850	77	75	180	80	75	66	--	1.0	1.5	6
1594	4000	100	60	180	60	87	80	--	1.7	1.5	--
397	4096	96	64	---	--	--	--	--	1.5	1.2	5
408/407	4294	92	70	180	60	67	70	60	1.3	1	6
997	4692	102	69	180	85	88	80	--	1.5	0.7	--
811(Dist.)	6020	105	86	180	50	--	57	--	1.2	1.1	10

TABLE 14. *Cercidiphyllum genesevianum* sp. nov.

Total number of specimens: 120

Ranges:

Smallest: Length 18 mm. Width 10 mm. Area 120 sq. mm. (# S 1305 Genesee, Alberta)
Largest: Length 105mm. Width 86 mm. Area 6020 sq. mm. (# S 811 Genesee, Alberta)
P.A. 45-105; W.S. 55-90; O.S. 45-90; S.S. 45-75; L/W 1.0-2.0; V.I.# 0.7-6.5; V.T.# 4-10.

Number of complete specimens studied for analysis: 71

P.A. Mean: 68 W.S. Mean: 73 O.S. Mean: 70 S.S. Mean: 61 L/W Mean: 1.4

<u>P.A.</u>	<u>Freq.</u>	<u>W.S.</u>	<u>Freq.</u>	<u>O.S.</u>	<u>Freq.</u>	<u>S.S.</u>	<u>Freq.</u>	<u>L/W</u>	<u>Freq.</u>
50	3	55	2	50	2	45	1	1.0	7
55	1	57	1	55	4	50	9	1.1	7
60	30	58	1	56	1	55	2	1.2	14
65	4	60	12	57	1	60	16	1.3	11
70	15	62	3	60	9	65	14	1.4	6
75	2	63	1	62	1	70	8	1.5	11
80	10	65	10	65	7			1.6	2
85	1	70	6	66	1			1.7	6
90	2	75	14	68	1			1.8	5
95	1	77	1	70	14			1.9	1
100	1	80	5	72	1			2.0	1
105	1	82	2	75	8				
		85	5	77	1				
		86	1	78	2				
		87	5	80	10				
		88	1	82	1				
		90	1	85	1				
				87	5				
				90	1				

TABLE 15. "t" test

<u>Species</u>	<u>n</u>	<u>V.I.#</u>	<u>df</u>	<u>"t" at 5%</u>	<u>Obtained "t"</u>
<i>C. genesevianum</i>	60	1.8 X	81	2.00	1.5
<i>C. japonicum</i> (long shoot)	23	0.9 X			

n - sample number

df - degrees of freedom

V.I.# - vein islet number

The obtained "t" value of 1.5 indicates that the difference between the vein islet numbers of the two samples is not significant at 5% level.

TABLE 16. *Cercidiphyllum flexuosum* (Hollick) n. comb.

<u>Sp. #</u>	<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
908	152	19	12	80	60	60	60	65	1.6
1014 (B)	238	21	17	130	60	55	60	60	1.2
1592	418	33	19	100	60	60	55	50	1.7
1590	506	33	23	160	95	57	65	60	1.4
1078 (B)	600	29	31	135	85	60	70	60	0.9
1039 (A)	684	38	27	100	45	62	55	60	1.4
850	744	36	31	120	60	55	55	60	1.2
1585	814	37	33	150	80	65	60	60	1.1
1067	820	41	30	100	60	65	60	62	1.4
1032	840	42	30	80	60	50	55	60	1.4
180	880	40	33	100	60	65	60	60	1.2
310	946	43	33	140	60	60	60	60	1.3
858	1012	41	37	120	65	55	60	50	1.1
797 (Lo)	1012	46	33	120	60	55	55	62	1.4
292	1140	45	38	120	60	60	60	52	1.2
767	1216	48	38	135	60	60	60	60	1.3
825	1280	48	40	120	60	55	50	50	1.2
776	1316	47	42	140	60	55	55	40	1.1
2848 (A)	1408	47	44	120	70	50	60	55	1.1
911 (Lo)	1472	46	48	150	75	60	65	52	1.0
807	1504	48	47	150	65	60	55	60	1.0
294	1568	48	49	120	60	60	60	60	1.0
851	1696	48	53	150	65	60	57	60	0.9
885	1700	51	50	130	60	60	60	55	1.0
181	1824	57	48	110	60	60	60	60	1.2
276	1836	51	54	140	60	60	57	50	0.9
296	1942	51	58	140	60	55	60	50	0.9
866	2080	60	52	160	75	60	60	50	1.1
300 (Lo)	2128	57	56	145	65	55	55	50	1.0
866	2280	60	57	140	70	60	60	55	1.0
794/777	2394	63	57	120	60	50	50	55	1.1
1619 (Lo)	2646	63	63	150	70	60	60	55	1.0

TABLE 16. Cont'd.

<u>Sp. #</u>	<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
949(B)	2660	70	57	125	60	60	60	55	1.2
867	2684	61	66	95	85	60	60	50	0.9
942	3300	75	66	140	60	60	60	55	1.1
1580	3354	68	74	140	80	55	60	50	0.9
368	3360	70	72	120	65	55	57	60	1.0
370	3408	72	71	160	60	60	60	60	1.0
820	2088	54	58	180	80	65	65	60	0.9
843	2108	51	62	180	90	60	70	65	0.8
2858	2200	55	60	180	80	67	70	60	0.9
187(Lo)	2304	54	64	180	85	60	65	50	0.8
1050	2352	56	63	180	80	67	70	57	0.9
1025(Lo)	2400	60	60	180	85	55	60	50	1.0
1048(Lo)	2480	60	62	180	80	62	62	50	1.0
844(B)	2520	63	60	180	70	70	75	60	1.0
2855	2552	58	65	180	60	50	60	50	0.9
2846	2684	61	66	180	70	55	65	55	0.9
1304(B) (Lo)	2688	64	64	180	90	70	70	60	1.0
1053(A)	2720	60	68	180	80	60	65	50	0.9
375	2800	60	70	180	85	60	65	57	0.9
2873	2814	63	67	180	70	70	70	65	1.0
873	2982	63	71	180	70	65	60	65	0.9
317	3500	70	75	180	80	60	70	55	0.9
851	3600	72	75	180	70	60	60	60	1.0
848	3652	66	83	180	75	60	70	55	0.8
877/920	3680	69	80	180	70	65	65	50	0.9
787	3808	68	84	180	70	60	70	55	0.8
808	3840	72	80	180	60	60	60	55	0.9
2857	3942	73	82	180	90	55	60	55	0.9
1045	3952	77	77	180	60	60	60	52	1.0
882	4032	72	84	180	80	55	60	50	0.9
214	4200	75	84	180	75	60	70	55	0.9
1015	4316	78	83	180	65	60	70	60	0.9
780	4600	75	92	180	80	60	70	55	0.8

TABLE 16. Cont'd.

<u>Sp. #</u>	<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
916	5146	83	93	180	60	55	60	60	0.9
873	5376	84	96	180	80	60	70	50	0.9
924	5600	80	105	180	85	60	55	60	0.8
840	5712	84	102	180	90	55	60	60	0.8
218	6000	90	100	180	60	50	60	60	0.9
825	6068	82	110	180	70	60	60	60	0.7
839	6440	92	105	180	60	70	60	60	0.9
1584	7130	93	115	180	70	62	65	60	0.8

TABLE 17. *Cercidiphyllum flexuosum* (Hollick) n. comb.

Sp. #	Area	L	W	Base	P.A.	W.S.	O.S.	S.S.	L/W	V.I.#	V.T.#
908	152	19	12	80	60	60	60	65	1.6	10.5	--
1014(B)	238	21	17	130	60	55	60	60	1.2	8	5
1590	506	33	23	160	95	57	67	60	1.4	7	--
1039(A)	684	38	27	100	45	62	55	60	1.4	12	3
850	744	36	31	120	60	55	55	60	1.2	8	5
234(P)	902	41	33	120	60	60	60	60	1.2	7	--
894(Lo)	962	38	38	115	--	65	70	--	1.0	5	7
1059	1008	42	36	120	60	60	60	60	1.2	5	--
1064(Lo)	1174	44	40	130	70	60	60	55	1.1	4.5	4
767	1216	48	38	135	60	60	60	60	1.3	3	5
825	1280	48	40	120	60	55	50	50	1.2	9	4
776	1316	47	42	140	60	55	55	40	1.1	10	6
911(Lo)	1472	46	48	150	75	60	65	52	1.0	5	5
248(Lo)	1496	51	44	140	60	60	60	57	1.2	3	8
851	1696	48	53	150	65	60	57	60	0.9	8	14
885	1700	51	50	130	60	60	60	55	1.0	5.5	12
276	1836	51	54	140	60	60	57	50	0.9	7	--
866	2080	60	52	160	75	60	60	50	1.1	2.5	8
300(Lo)	2128	57	56	145	65	55	55	50	1.0	5.5	11
866	2280	60	57	140	70	60	60	55	1.0	10	16
794/777	2394	63	57	120	60	50	50	55	1.1	9	12

TABLE 17. Cont'd.

<u>Sp. #</u>	<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>	<u>V.I.#</u>	<u>V.T.#</u>
1619(Lo)	2646	63	63	150	70	60	60	55	1.0	7.5	11
867	2684	61	66	95	85	60	60	50	0.9	9	12
1580	3354	68	74	140	80	55	60	50	0.9	6.5	10
368	3360	70	72	120	65	55	57	60	1.0	11	15
370	3408	72	71	160	60	60	60	60	1.0	9	12
310	2100	50	63	180	80	70	60	60	0.8	6.5	9
843	2108	51	62	180	90	60	70	65	0.8	10	14
1050	2352	56	63	180	80	67	70	57	0.9	2	6
1064	2420	55	66	180	60	55	60	--	0.8	7	
1048(Lo)	2480	60	62	180	80	62	62	50	1.0	6	10
844(B)	2520	63	60	180	70	70	75	60	1.0	4	8
1304(B) (Lo)	2688	64	64	180	90	70	70	60	1.0	10.5	22
375	2800	60	70	180	85	60	65	57	0.9	5	9
1059	2816	66	64	180	60	50	55	50	1.0	9	--
873	2982	63	71	180	70	65	60	65	0.9	10	8
775	3128	81	92	180	95	65	65	55	0.9	7	12
877/920	3680	69	80	180	70	65	65	50	0.9	12	14
284	3786	71	80	180	80	60	60	--	0.9	8	8
808	3840	72	80	180	60	60	60	55	0.9	5	7
1305	3920	70	84	180	70	60	--	60	0.8	10	8
379	3936	72	82	180	65	65	67	55	0.9	6	6
1045	3952	77	77	180	60	60	60	52	1.0	4.5	8

TABLE 17. Cont'd.

<u>Sp. #</u>	<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>	<u>V.I.#</u>	<u>V.T.#</u>
1015	4316	78	83	180	65	60	70	60	0.9	10	12
780	4600	75	92	180	80	60	70	55	0.8	10	--
324	4680	78	90	180	90	60	65	--	0.9	3.5	--
916	5146	83	93	180	60	55	60	60	0.9	12	--
840	5712	84	102	180	90	55	60	60	0.8	4.5	8
218	6000	90	100	180	60	50	60	60	0.9	9	--
825	6068	82	110	180	70	60	60	60	0.7	7.5	10
1035	6160	84	110	180	75	55	--	--	0.8	6	--

TABLE 19. *Populus tremuloides*. (Data from cleared slides).

<u>Slide #</u>	<u>Area</u>	<u>L</u>	<u>W</u>	<u>V.I.#</u>	<u>V.T.#</u>
68	168	18	14	16	48
80	416	25	25	15	62
65	490	32	23	6	28
67	638	33	29	14.5	42
74	684	38	27	6	14
62	780	39	30	5	28
78	960	40	36	7.5	28
66	974	51	43	10.5	38
69	1040	40	39	8	52
64	1280	48	40	9	40
63	1340	49	41	15	44
70	2552	58	66	12	34
71	2600	60	65	11	43
72	2948	66	67	11	44
<u>Mean:</u>				<u>10</u>	<u>39</u>

TABLE 20. *Cercidiphyllum cuneatum* (Newberry) n. comb.

<u>Sp. #</u>	<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
312/309	374	33	17	70	40	60	50	50	2.0
885	431	34	19	100	50	60	55	50	1.8
959	538	31	26	160	60	60	55	50	1.2
1043	734	44	25	95	60	55	55	55	1.8
998	738	41	27	120	60	50	50	50	1.5
914(A)	836	38	33	120	60	55	40	50	1.1
279	--	--	36	130	60	50	45	55	--
1051(B)	1040	39	40	140	50	55	55	50	1.0
870	1156	51	34	100	60	55	45	60	1.5
2725(B)	1176	42	42	165	70	75	60	50	1.0
1598	1190	47	38	160	60	60	60	60	1.2
813	1260	45	42	120	60	55	45	60	1.1
225	--	--	32	120	55	50	45	50	--
206	1284	55	35	120	50	60	50	55	1.6
1584(Lo)	1344	48	42	180	60	55	60	60	1.1
376	1360	40	51	160	80	55	60	50	0.8
2720(Lo)	--	--	48	160	80	55	60	50	--
311	1504	48	47	145	55	50	50	50	1.0
939	1662	58	43	140	60	50	48	50	1.3
1330	1768	51	52	160	60	60	45	50	1.0
1080(P)	1792	48	56	180	50	60	50	--	0.9
885	1856	58	48	150	60	60	50	50	1.2
864	1890	63	45	120	55	50	46	60	1.4
1071	1904	51	56	150	70	52	47	60	0.9
301(P)	--	--	43	145	60	57	60	--	--
1066(#2)	--	--	63	180	65	50	50	--	--
855(A)	1984	48	62	180	60	62	60	65	0.8
1600	2080	52	60	180	70	50	57	60	0.9
867	2176	51	64	180	60	50	65	--	0.8
283	2200	50	66	180	60	58	55	65	0.8
2828	2240	60	56	160	60	55	45	50	1.1
395(Lo)	2242	59	57	160	60	52	52	50	1.0
1069	2300	50	69	150	60	50	45	65	0.7

TABLE 20. Cont'd.

<u>Sp. #</u>	<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
2845	2318	61	57	175	60	52	52	60	1.1
1085(Lo)	2340	65	54	150	60	50	50	50	1.2
885	2380	51	70	180	60	50	42	55	0.7
2727	2394	63	57	125	60	50	45	60	1.1
813	2470	77	65	140	60	50	45	45	0.9
1044	2480	60	62	140	55	60	57	60	1.0
874(Lo)	2496	72	52	120	45	55	45	--	1.4
864	2516	49	77	180	70	57	55	--	0.6
1018(B)	2520	63	60	150	60	60	50	60	1.0
977(A) (Lo)	--	--	64	180	65	55	50	--	--
2717	2614	56	70	180	60	57	50	--	0.8
897	2680	60	67	120	45	55	65	55	0.9
1031	2814	63	67	175	75	57	48	60	1.0
369(Lo)	2940	70	63	140	60	60	50	50	1.1
250	2940	63	70	135	60	50	50	--	0.9
100	3250	65	75	160	60	60	60	50	0.9
207	3250	65	75	140	55	60	48	--	0.9
1586(B)	3312	72	69	130	60	50	48	55	1.0
374	--	--	73	160	60	50	50	50	--
355(Lo)	3360	72	70	180	60	50	55	60	1.0
333/322	3552	74	72	140	60	50	40	50	1.0
326(Lo)	3650	75	73	165	60	50	45	60	1.0
957(A)	4104	76	81	180	60	60	55	60	0.9
245	4160	65	96	180	80	60	48	60	0.7
982	4200	90	70	180	45	53	58	50	1.3
308	4312	77	84	180	70	55	55	55	0.9
2827	5884	91	97	180	40	50	45	--	0.9
830	6324	93	102	180	70	50	58	50	0.9
874(Lo)	340	34	15	110	50	50	55	45	2.2
1072	672	36	28	140	60	55	55	55	1.3
358(A)	972	54	27	105	40	50	55	45	2.0
829	--	--	32	130	60	50	55	45	--

TABLE 20. Cont'd.

<u>Sp. #</u>	<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
1041	1176	49	36	150	60	55	55	50	1.4
286	1210	55	33	110	55	55	55	60	1.7
1321(B)	1440	54	40	150	60	50	50	55	1.3
295	1516	65	35	100	40	50	46	45	1.9
244	1744	57	38	100	40	50	45	48	1.5
813	1824	57	48	120	50	55	58	--	1.2
960	2240	70	48	140	55	50	45	--	1.5
271	583	38	23	130	60	60	40	55	1.6
995	728	42	26	120	60	60	50	50	1.6
409(Lo)	792	44	27	125	60	60	60	60	1.6
295	860	43	30	110	50	55	45	60	1.4
399/400	--	--	28	140	60	55	50	55	--
988(Lo)	934	50	28	150	45	50	40	50	1.8
874(Lo)	1270	56	34	140	60	50	50	40	1.6
235	1520	57	40	120	60	45	45	--	1.4
1016(A)	1646	65	38	120	55	50	40	50	1.7
805	1740	58	45	130	60	65	53	65	1.3
1304(A) (Lo)	1792	56	48	170	55	60	60	60	1.2
813	1878	64	44	130	60	60	58	60	1.5
328	1974	63	47	150	60	58	50	50	1.3
341	1984	62	48	120	40	55	50	40	1.3
884	2100	63	50	165	45	55	50	55	1.3
922	2200	66	50	180	60	55	55	60	1.3
1033(A)	2200	66	50	160	70	60	52	60	1.3
1078(A)	2240	60	56	180	60	55	50	--	1.1
884	--	--	66	180	70	60	55	60	--
988	2440	60	61	150	60	55	55	55	1.0
169	2816	66	64	180	60	55	53	--	1.0
863	2814	63	67	180	60	60	50	--	0.9
2716(A)	2814	63	67	180	65	70	65	60	0.9
306	2940	63	70	180	60	55	55	--	0.9
341	2946	68	65	125	40	55	45	--	1.0

TABLE 20. Cont'd.

<u>Sp. #</u>	<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>
1599	3360	71	71	180	55	65	65	60	1.0
1051(B)	3476	66	79	180	80	58	50	--	0.8
269/271	4048	76	80	180	90	65	60	--	1.0
883(B) (A)	4864	96	76	180	60	65	65	55	1.3
2718(A)	4920	90	82	180	60	65	50	55	1.1

TABLE 21. *Cercidiphyllum cuneatum* (Newberry) n. comb.

Sp. #	Area	L	W	Base	P.A.	W.S.	O.S.	S.S.	L/W	V.I.#	V.T.#
358(A)	972	54	27	105	40	50	55	45	2.0	3.5	6
295	1516	65	35	100	40	50	46	45	1.9	3	4
255	1800	60	45	140	60	50	58	50	1.3	1.5	--
813	1824	57	48	120	50	55	58	--	1.2	3	8
312/309	374	33	17	70	40	60	50	50	2.0	2.5	4
914(A)	836	38	33	120	60	55	40	50	1.1	2	--
279	864	36	36	130	60	50	45	55	1.0	2	--
338(P)	1184	37	48	160	60	55	55	55	0.8	1.5	4
813	1260	45	42	120	60	55	45	60	1.1	2	--
206	1284	55	35	120	50	60	50	55	1.6	2.5	6
376	1360	40	51	160	80	55	60	50	0.8	2	6
955	1394	41	51	150	65	65	57	--	0.8	3	5
2720(Lo)	1472	46	48	160	80	55	60	50	1.0	1	5
311	1504	48	47	145	55	50	50	50	1.0	3.5	4
1330	1768	51	52	160	60	60	45	50	1.0	1	--
394	1950	65	45	180	--	--	--	--	0.7	1.2	4
1600	2080	52	60	180	70	50	57	60	0.9	0.8	4
881(B)	2176	48	68	---	--	50	50	--	0.7	3.5	5
1018(B)	2520	63	60	150	60	60	50	60	1.0	3	--
298	2736	57	72	180	70	55	50	50	0.8	1.2	5
1053(B) (Lo)	2750	55	75	180	60	60	50	--	0.7	1.1	5

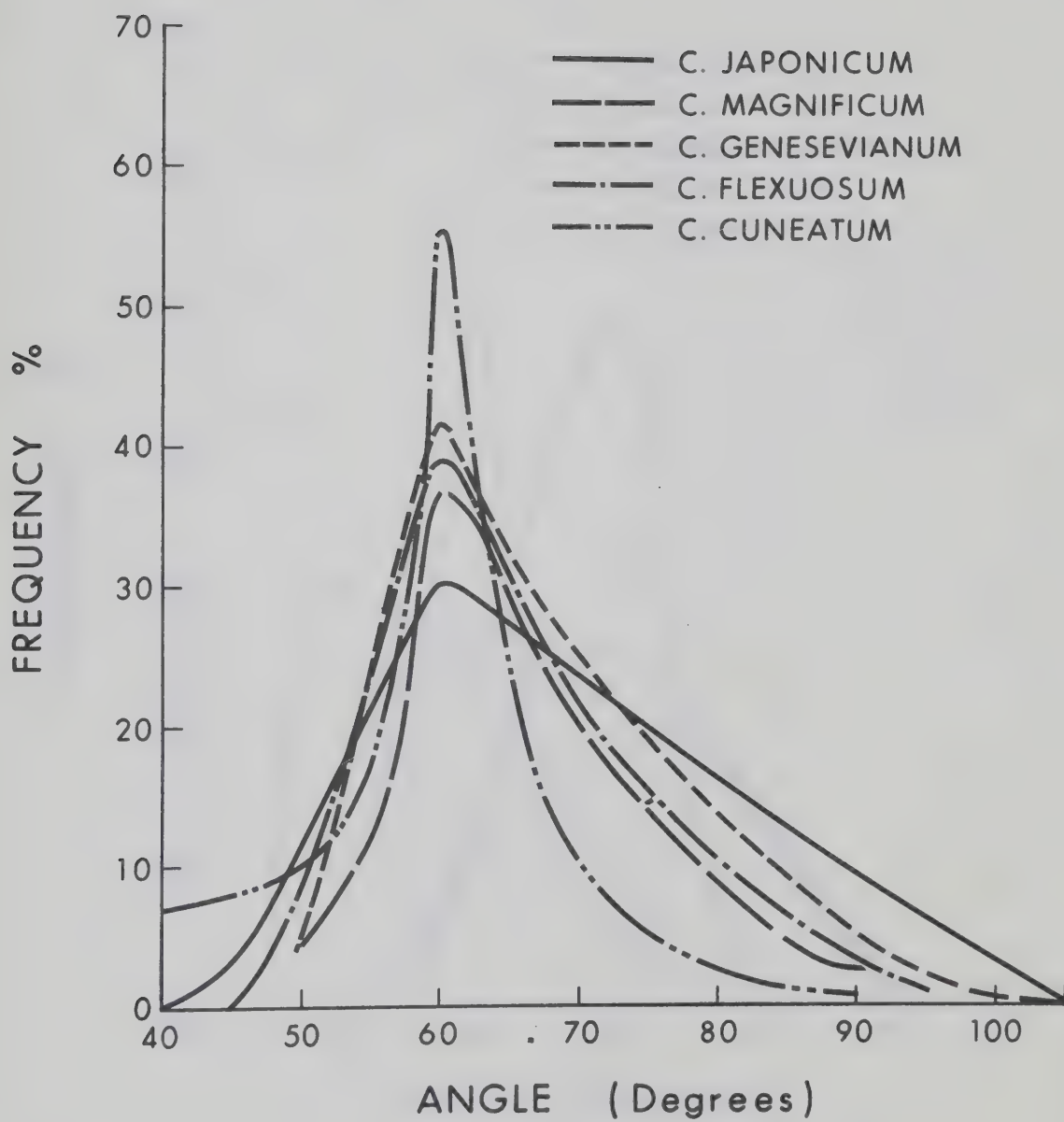
TABLE 21. Cont'd.

<u>Sp. #</u>	<u>Area</u>	<u>L</u>	<u>W</u>	<u>Base</u>	<u>P.A.</u>	<u>W.S.</u>	<u>O.S.</u>	<u>S.S.</u>	<u>L/W</u>	<u>V.I.#</u>	<u>V.T.#</u>
1031	2814	63	67	175	75	57	48	60	1.0	1	--
250(Dist.)	2940	63	70	135	60	50	50	--	0.9	1	6
1082	3050	61	75	180	50	60	60	--	0.8	4	4
797(Lo) (Dist)	3216	67	72	180	--	--	--	--	0.9	4	5
1586(B)	3312	72	69	130	60	50	48	55	1.0	1	--
374	3358	69	73	160	60	50	50	50	0.9	2	--
178	3360	60	84	150	65	50	55	50	0.7	1.5	--
245	4160	65	96	180	80	60	48	60	0.7	1	6
830	6324	93	102	180	70	50	58	50	0.9	1	5
1304(A) (Lo)	1792	56	48	170	55	60	60	60	1.2	2	--
1078(A)	2240	60	56	180	60	55	50	--	1.1	2	4
884	2404	56	66	180	70	60	55	60	0.8	1.3	--
988	2440	60	61	150	60	55	55	55	1.0	0.8	8
1341	2600	75	52	100	40	55	50	--	1.4	1.5	--
2716(A) (P)	2814	63	67	180	65	70	65	60	0.9	1	--
269/271	4048	76	80	180	90	65	60	--	1.0	2	--
884	4340	93	70	180	60	50	48	45	1.3	1	6
2718(A)	4920	90	80	180	60	65	50	55	1.1	1	4

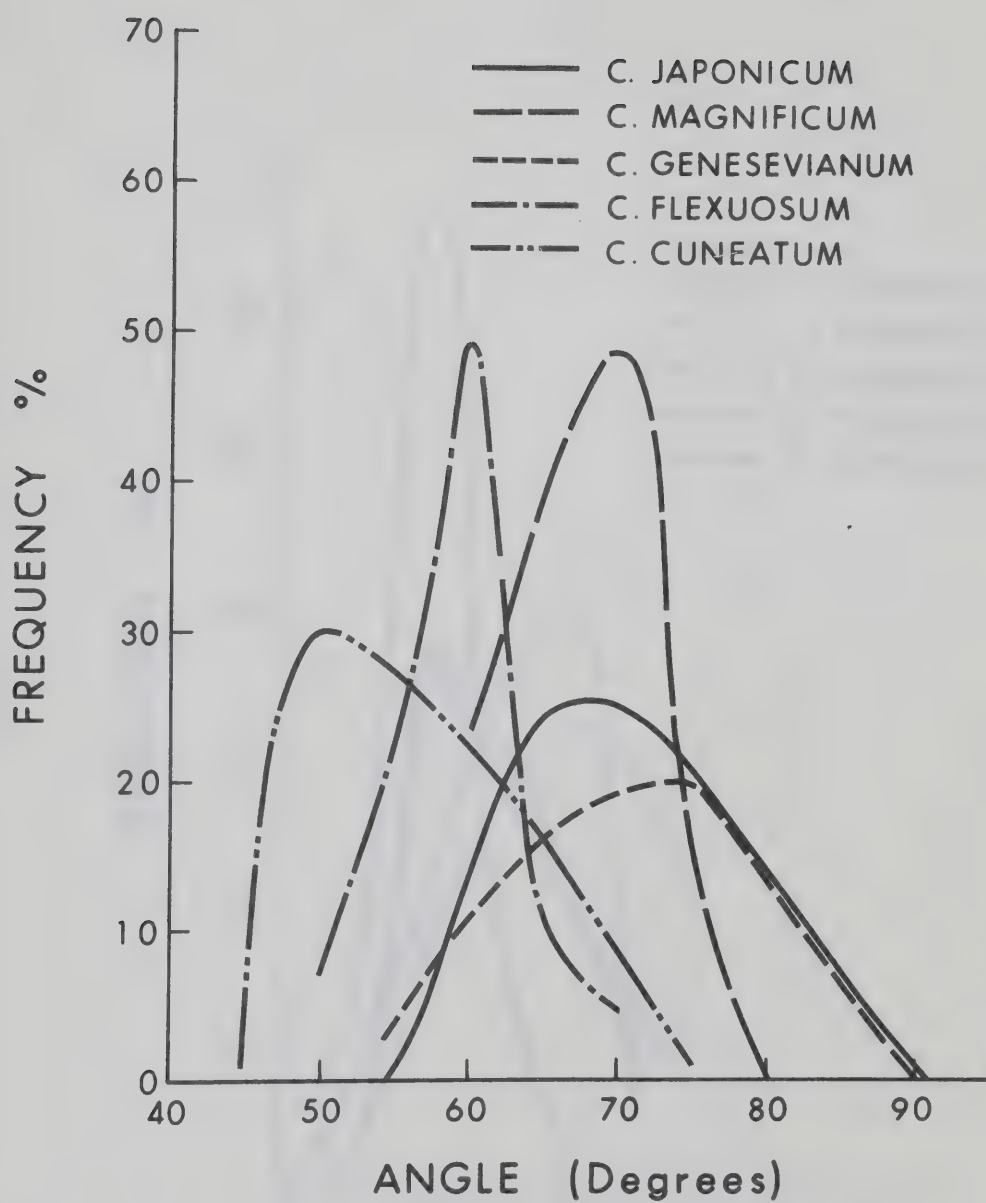
TABLE 23. *Cocculus trilobus* (Thunb.) D.C.

Data from cleared leaves. Leaves removed from herbarium material of Arnold Arboretum.

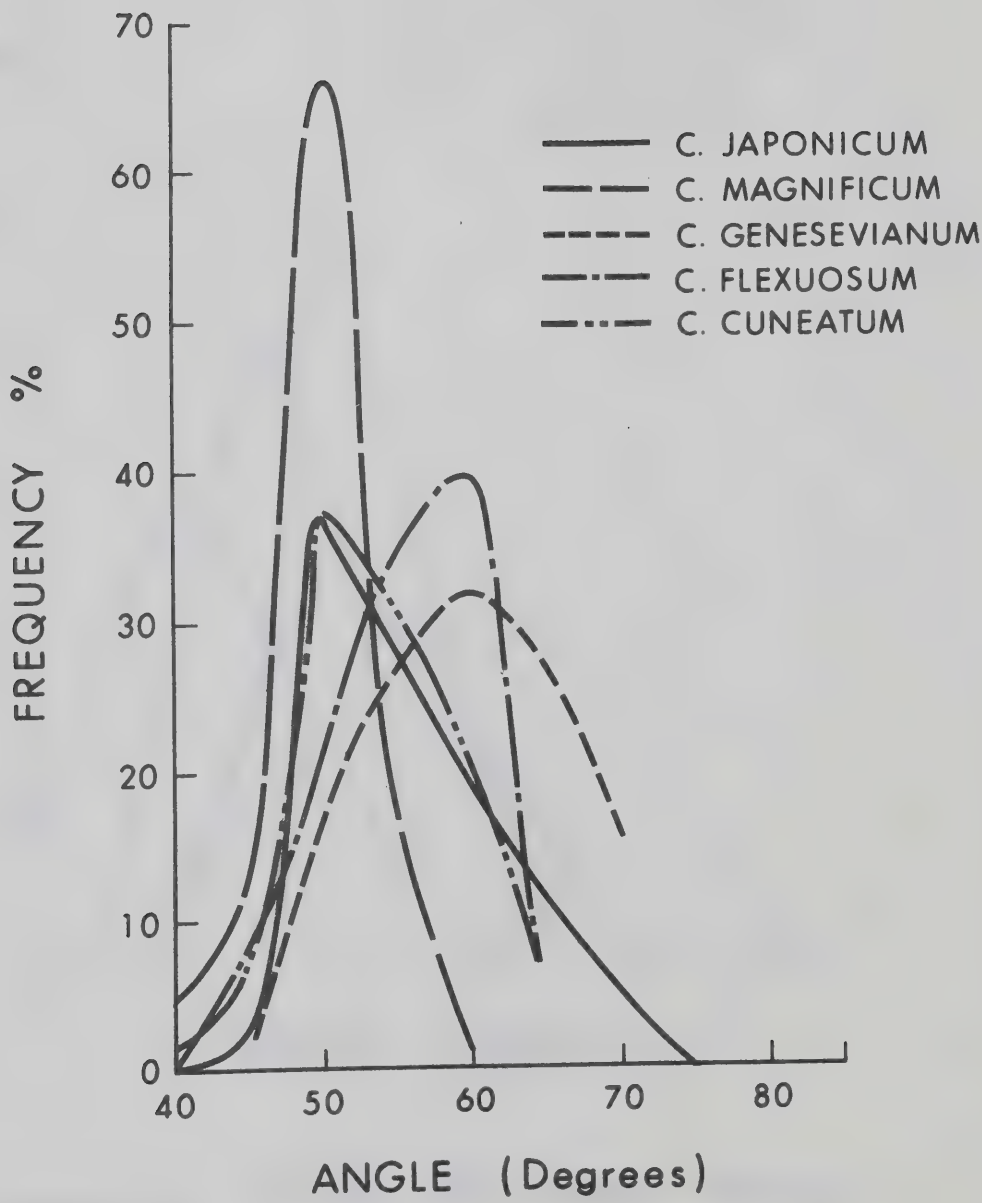
<u>Slide #</u>	<u>L</u>	<u>W</u>	<u>Area</u>	<u>V.I.#</u>	<u>V.T.#</u>
87	22	16	234	4	3
113	29	29	580	4	6
83	37	30	740	4.5	3
88	39	35	910	4.5	2.5
85	59	44	1760	5	6
115	65	49	2156	2	4
86	63	55	2310	2.3	5
114	66	60	2640	2.2	4
<u>Mean:</u>				<u>3.6</u>	<u>4.2</u>



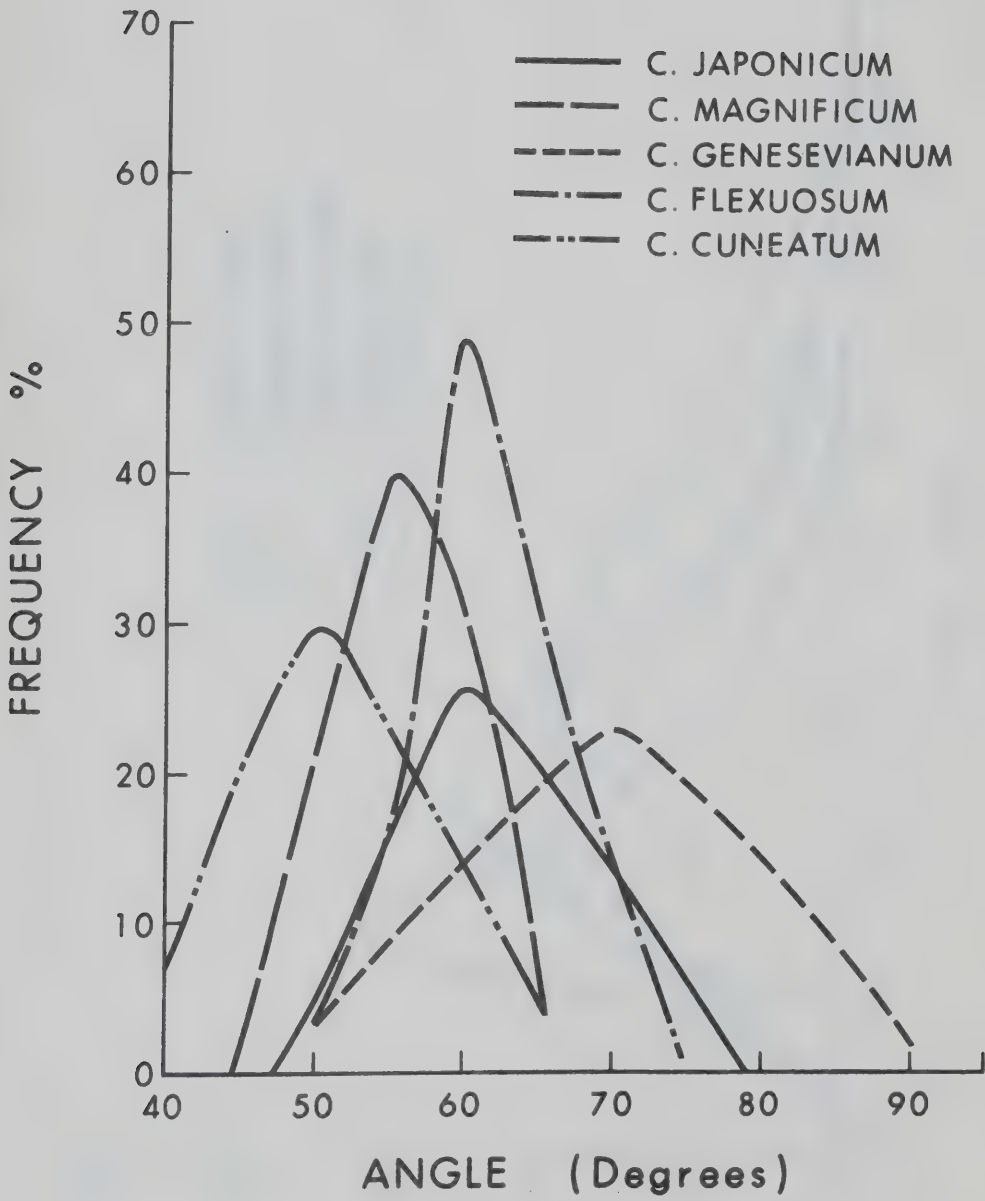
GRAPH 1 PRIMARY ANGLE



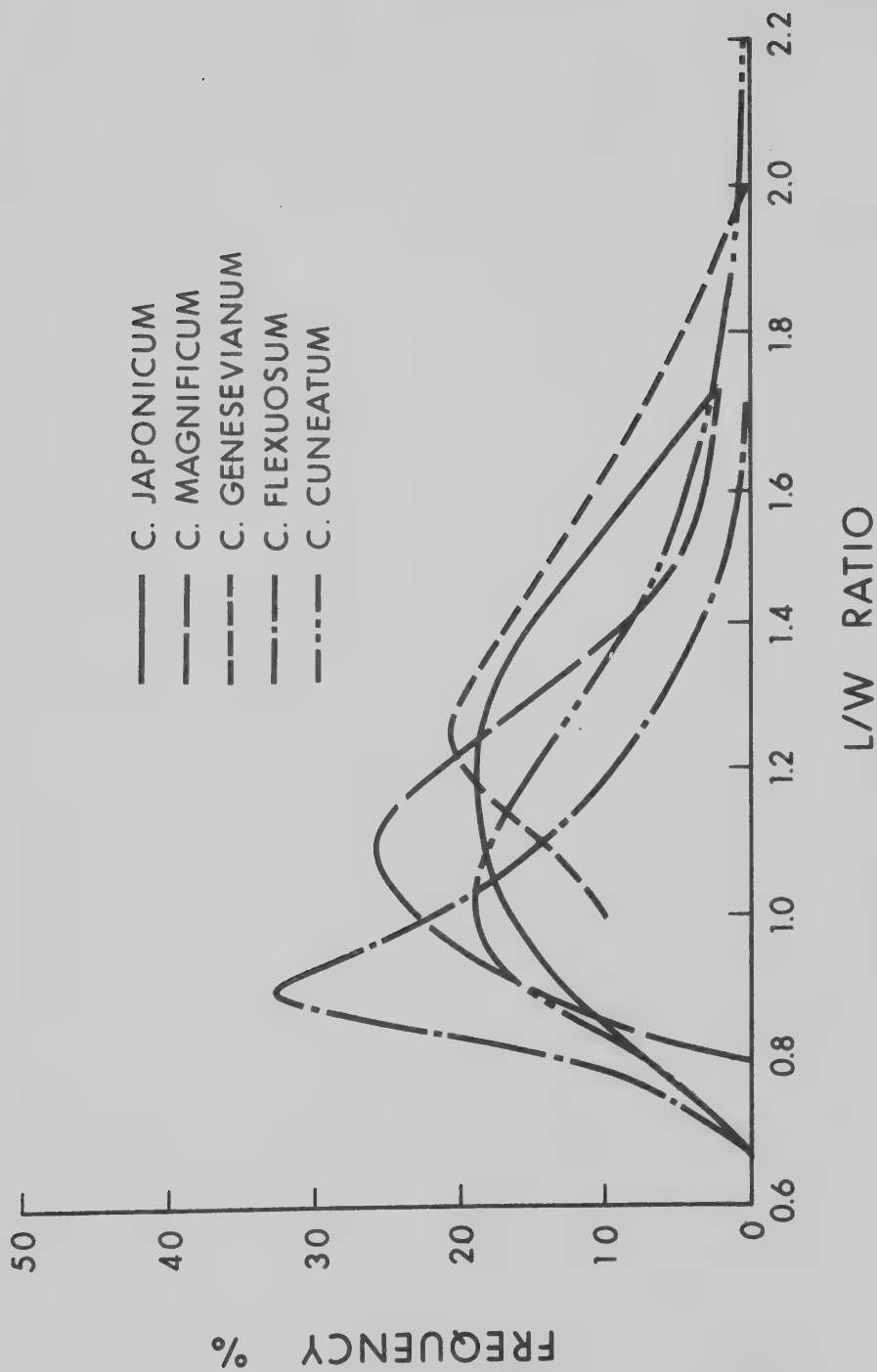
GRAPH 2 WEAK SECONDARY ANGLE



GRAPH 3 STRONG SECONDARY
 ANGLE



GRAPH 4. OUTER SECONDARY ANGLE



GRAPH 5 L / W RATIO

B30038